AGRICULTURAL ENGINEERING

NOVEMBER • 1952

ASAE Winter Meeting • Chicago, Ill., December 15-17

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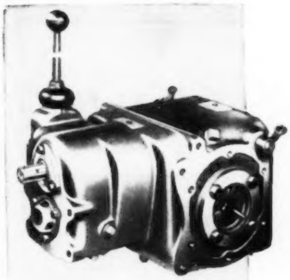

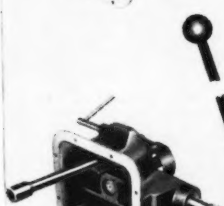

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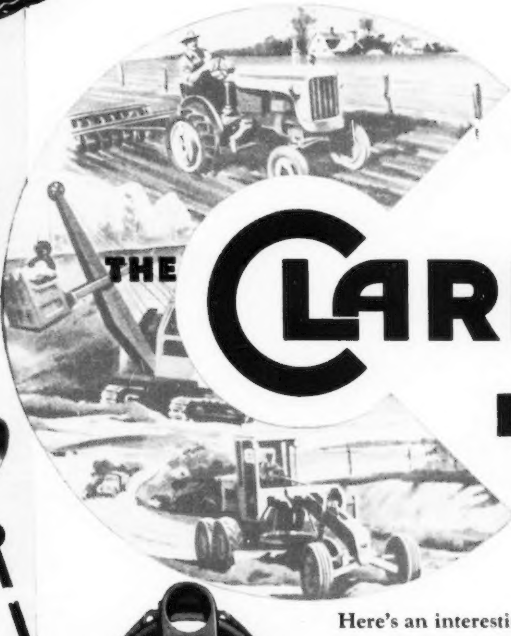

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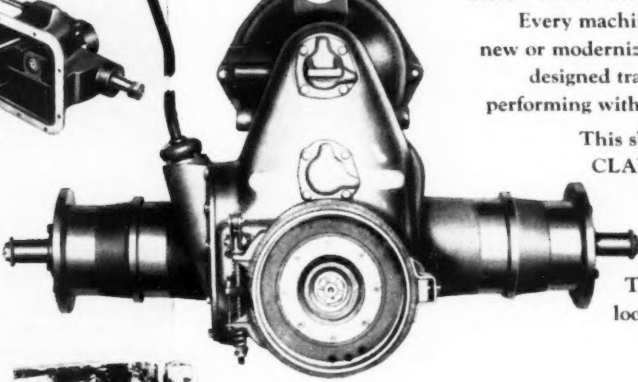

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AGRICULTURAL ENGINEERING

Established 1920

CONTENTS FOR NOVEMBER, 1952

Vol. 33, No. 11

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INDEX TO ADVERTISERS

TO OUR READERS: Advertisers in this issue present their products and services for your scrutiny, with confidence in their engineering merit and capacity to meet the requirements for which intended, and with confidence in your appreciation of these contributions to engineering progress in agriculture.

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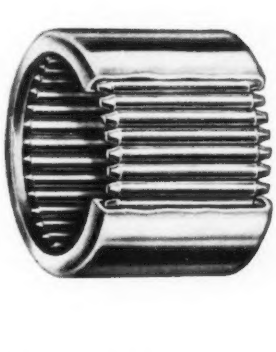

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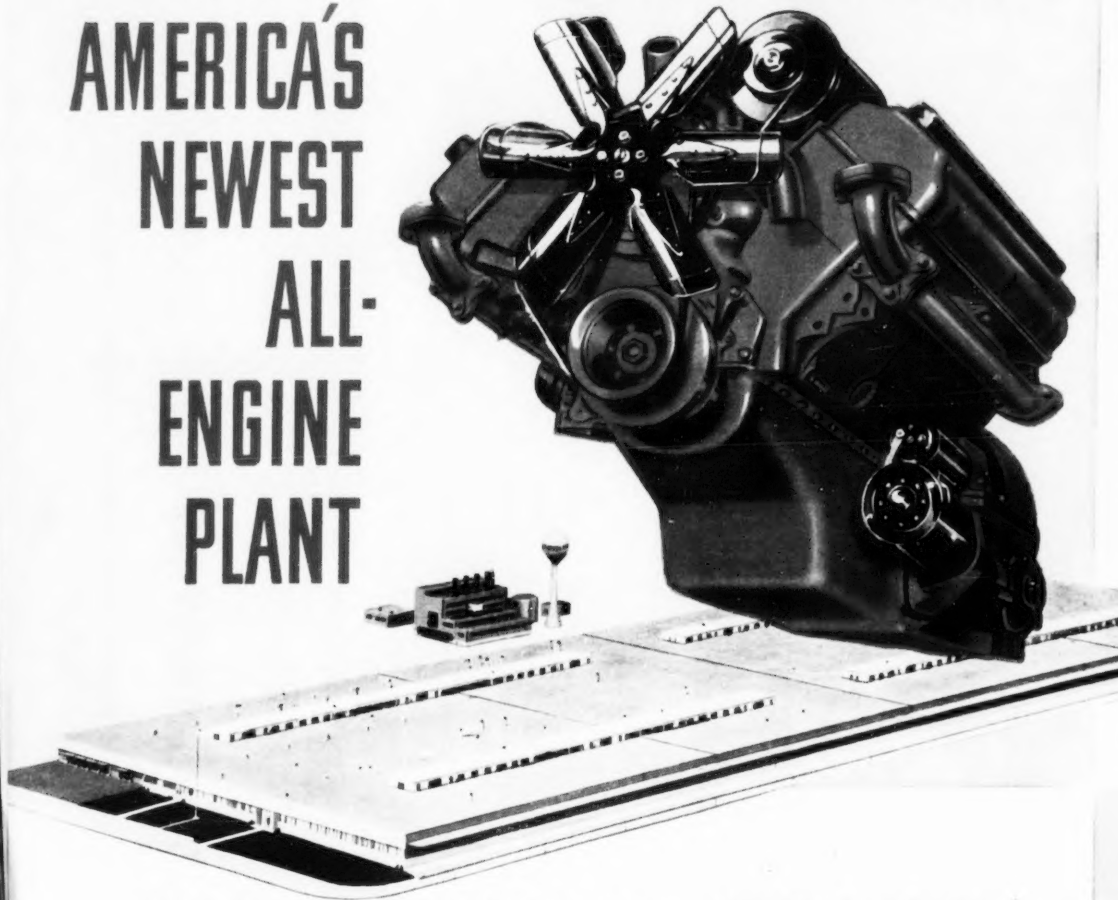

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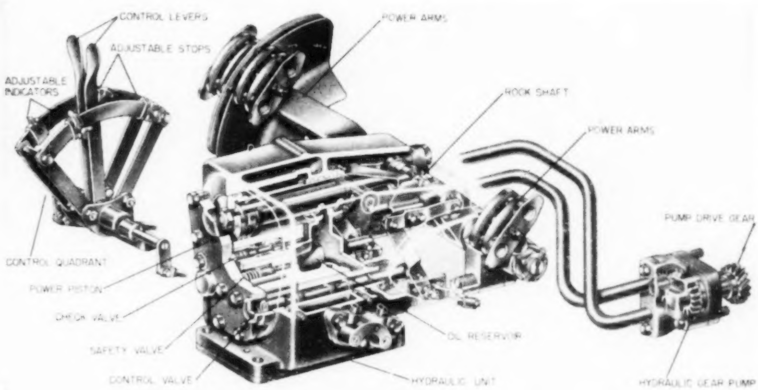

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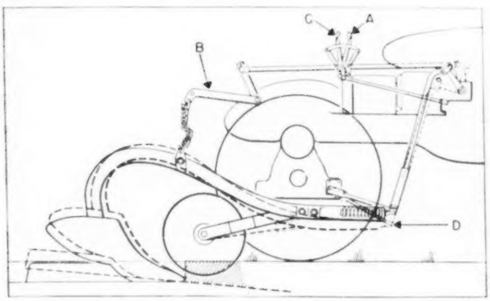

Precise depth control results from Farmall Touch-Control design. Control lever (A) actuates rear rockshaft (B) to raise and lower plow. Control lever (C) raises or lowers drawbar (D) to change depth.

Farmall Touch-Control is equally adaptable to front or rear-mounted implements. Above: lifting two-furrow, rear-mounted plow to cross a grassed waterway. Fast lifting action provides for uniform furrow ends.

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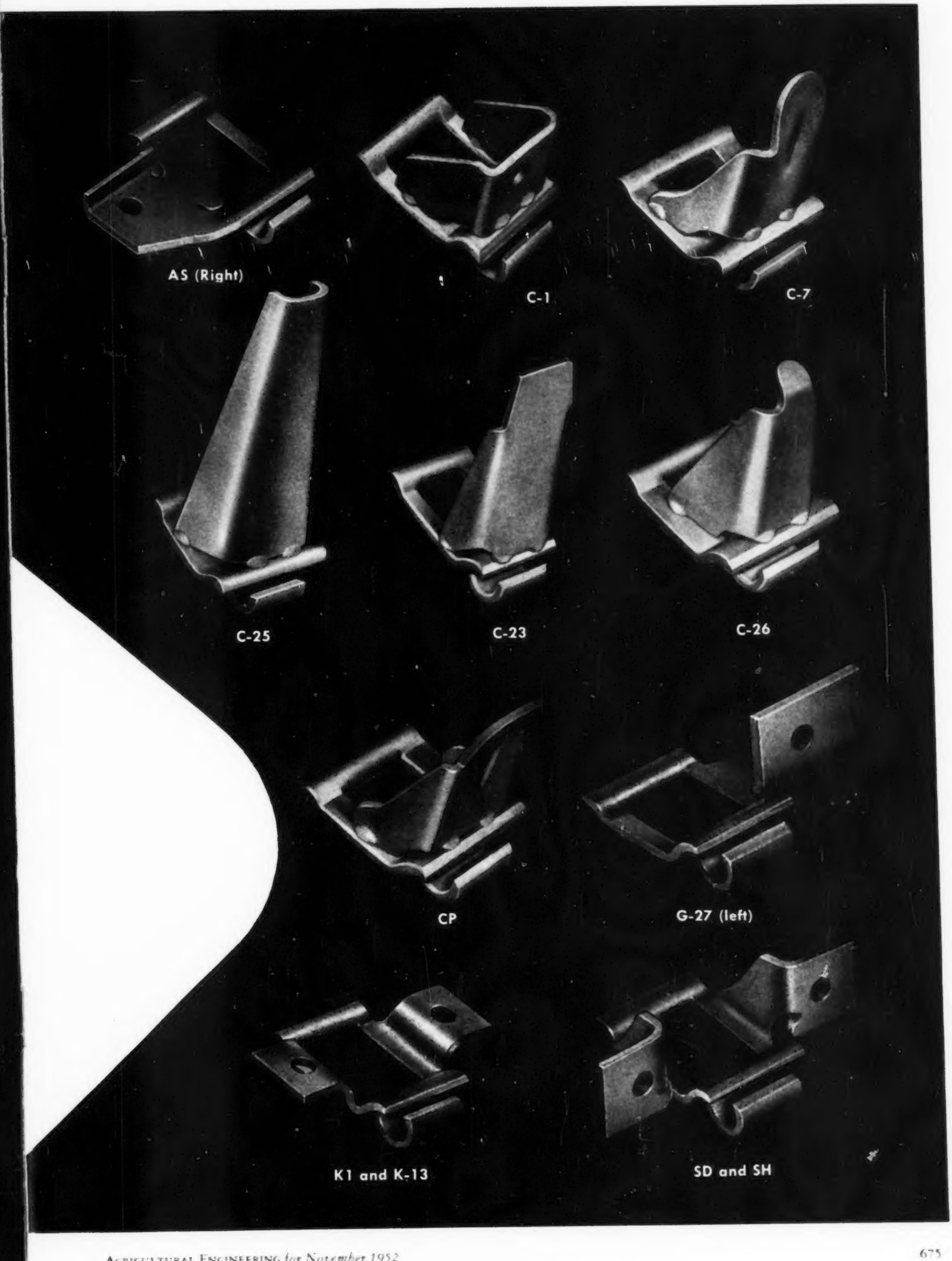
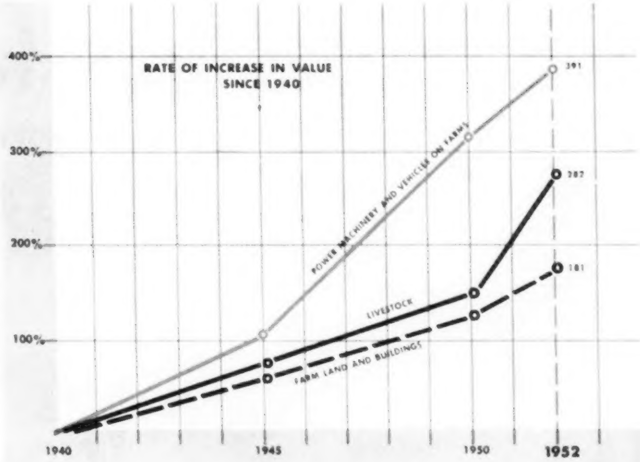

AS (Right)
C-1
C-7
C-25
C-23
C-26
CP
G-27 (left)
K1 and K-13
SD and SH

New measure of machinery value



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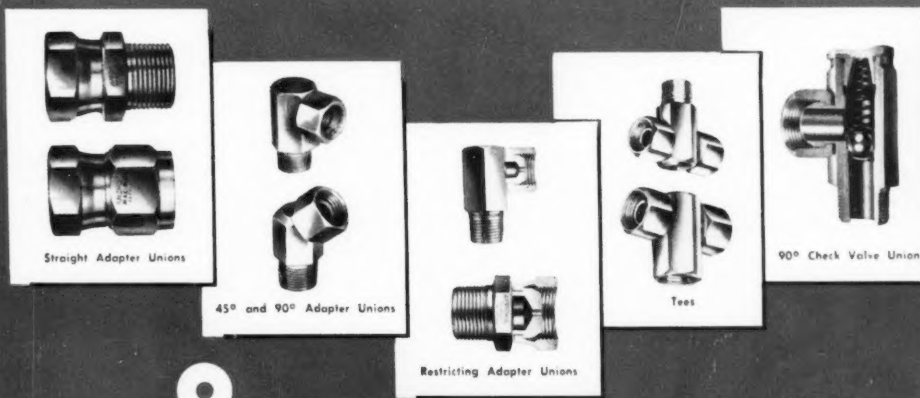

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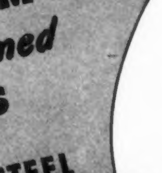

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EDITORIAL

Public Relations

MOST engineers apparently appreciate the positive values of good public relations. Many, however, are less certain as to specific measures by which their own public relations and those of the whole engineering profession might be improved.

Some engineers have learned by unfortunate personal experience or observation that publicity does not necessarily contribute to improved public relations.

Certain elements of the non-technical press have been known to take the accurate, carefully qualified statement of an engineer and misinterpret it into a sweeping, sensational, inaccurate, and misleading generalization. That has helped produce publicity-shy engineers.

Such incidents may be due in part to failure of the non-technical writer and editor to comprehend the nature of engineering. They may also be due in part to the engineer's limitations in interpreting, for the non-technical writer and editor, the true human interest significance of his statement. At any rate they typify the problem of improving relations between technical and non-technical elements of a population. They suggest a continuing search for a common meeting ground in language, interest, and understanding.

Engineers need not be overly concerned if they may have to meet their non-engineering public more than halfway in finding a common basis of understanding. It should be easier for most engineers to think and talk as human beings, even where their particular specialty is concerned, than for most humans to learn to think and talk as engineers.

Any interest of the non-engineering public in engineering activities and progress is highly subjective and personal, related to the motivations, drives, beliefs, prejudices, emotions, conflicts, competition, successes and failures of the individuals who collectively are the public. They want to know what engineering progress is of immediate practical significance to them. Concerning any particular development, can they drive it, eat it, or sell it? Will it directly benefit them in terms of earnings, living and working conditions, or recreation? What does it mean in the everyday language of life and living which they understand?

That is the standard by which non-technical news men and the non-technical public measure their interest in engineering. It calls for thinking, speaking and writing in terms of those human aims and ends of engineering which are the directing force behind the development and application of engineering means. It demands of the engineer that he know and be able to explain in terms of human values why his work is worth while, or what it is producing. Ability to explain engineering in these human terms does not come easy. It has to be developed by conscious effort. It is worth developing. It is an important part of the difference between a true engineer and a technician.

While large sections of the public cannot be trained as engineers, considerable is being done and still more might be done to indoctrinate them in the nature of engineering.

They can be shown that the automobiles in which they ride are about one per cent the result of new ideas, and about 99 per cent the result of more than half a century of patient, careful, progressive development and refinement in the application of new and old information and ideas.

They can be helped to understand that television is a product, not of magic, but of the orderly, step-by-step recognition and application of physical facts concerning the properties and behavior of energy and a wide variety of materials.

They can be reminded that improvements in farm machines, structures, electrification, and measures for soil and water control do not just happen. Engineers contribute vital elements to their development.

They can be made to realize that engineering involves a lot of unspectacular work with abstract facts and figures; that its individual steps forward are commonly short and halting; that its new products commonly have "bugs" to be eliminated by further refinement; that its new information is ordinarily in the form of bits applicable only to limited and specific types of situations; that its developments are generally evolutionary in nature, rather than revolutionary in terms of day-to-day headlines; that its significance is cumulative, and adds up to much of the difference between their lives and those of their grandparents or those of peons and peasants in countries less advanced in engineering.

They can be assured that engineering will never provide them with a ready-made paradise, but that it will keep giving them new and improved means by which they themselves can work more effectively toward more satisfactory living.

On that basis of understanding, we believe, public reaction to engineering would be generally favorable, and would insure to engineers the opportunity to continue their work with maximum cooperation and minimum interference.

Helping develop favorable relations with his public is an important part of every engineer's job, in his own interest as well as that of his public. The agricultural engineer's public includes the organization employing him, his immediate and prospective customers and clients, some important group of farmers, industries serving agriculture, other branches of engineering, and, as consumers of agricultural products, the whole human race.

Definitions and Objectives

ENGINEERING was defined in a variation of the usual wording in an address, entitled "Challenges Ahead," by Karl D. Butler, farm counselor, Avco Mfg. Corp., before the North Atlantic Section of the American Society of Agricultural Engineers, at its meeting in Orono, Maine, in August. Quoted by him from an unnamed source, the definition reads: "Engineering is a profession in which the art of applying imagination, common sense, native ingenuity, scientific principles, technical training, professional knowledge, and practical experience is exercised for the use and convenience of man in the conception and design of tools, machines, and structures, and in the direction of their economic construction and operation."

In its application to agricultural engineering, this definition merits consideration in association with long-range objectives outlined in the conclusion to Mr. Butler's address, as follows:

"For the long pull, I believe we are all reaching for the same goal — the engineer, the farmer, the industrialist, the scientist, the businessman and the housewife who buys the products of our toil. At heart I believe everyone of us wants to help build better men, women and children — and a better place in which to live.

"Through servicing the great agricultural industry, you are not only helping yourselves, but you are helping farmers to more efficiently produce more of the things that make people and nations strong. More and better meat, milk, eggs and other good foods, plus fibers, are essential for good health and our *spiritual well-being. To me, this is what agriculture is all about.*

"The challenge ahead then is to better service the farmer and mankind. As engineers, as scientists, as industrialists or whatever our endeavor, we must be alert to the trends and changes going on. We must have convictions. We must be aggressive and courageous. In no other way can we meet the challenge, the goal of which is to build a stronger and better people.

"I have great confidence you will do your part — and do it well!"

A nominal quota of common sense and native ingenuity, backed by a knowledge of scientific principles, technical training, professional knowledge and practical experience, should certainly put the agricultural engineer in a favorable position to serve agriculture effectively in working toward its long range objectives. The indicated combination of knowledge and abilities is currently in active demand, and the demand seems to be increasing more rapidly than the supply of men so equipped.

AGRICULTURAL ENGINEERING

VOL. 33 NOVEMBER, 1952 NO. 11

Analysis of the Cutting Action of a Mower

By Robert A. Kepner

MEMBER ASAE

RECENT years have seen considerable development work and important advances in nearly all types of forage-harvesting equipment except the mower. New types of hay rakes have been developed and their actions studied analytically and in the field; automatic-tying hay balers are being continually improved and are becoming increasingly popular, and field forage choppers, now widely used, are undergoing further development. The present-day mower, however, is about the same, both in principle of operation and in construction of the cutter bar, as it was 20 years ago. From the standpoint of maintenance and repair it still remains one of the most troublesome pieces of machinery on the farm.

This paper was prepared expressly for AGRICULTURAL ENGINEERING. The author: ROBERT A. KEPNER, associate agricultural engineer at the agricultural experiment station, University of California, Davis.

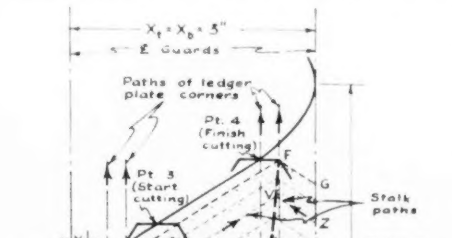


Fig. 1 Cutting graph for conventional mower with smooth knife blades, serrated ledger plates, and a 3-in feed rate. Paths of cutting elements and stalks being deflected to the cutting line are plotted with respect to the ground. Stalks originating in the shaded area are all cut along line EF

The current trend toward higher speeds in farm operations and the demand for a mower which will be durable and do a good job of cutting at these high speeds are now causing an active interest in possible mower improvements. There is no doubt that this interest will become increasingly active, with the inevitable improvement of the present machine and the introduction of some radically different types of mowers.

In studying a proposed design or a modification of an existing machine, the engineer should attempt to predict or evaluate the cutting action of the device, particularly in regard to the probable quality of the cutting job and the effect of the cutting action on the mechanical requirements of the mower. Some objectives to be considered in regard to the cutting action are as follows:

1 Minimum deflection of stalks by the machine prior to cutting is essential for uniform stubble length.

2 The included angle between the cutting edges must be small enough so that stalks will be cut rather than expelled forward.

3 For clean cutting and minimum power requirements, it is desirable to have a high knife velocity during the entire cutting portion of the stroke. This is important because much of the cutting, particularly when the knife is not down tight against the ledger plates, depends on a combination of impact and shear rather than on shear alone.

4 Cutting over a relatively large part of the cycle tends to reduce stalk deflection from the rear and reduces the magnitude of cutting forces, as will be brought out later in this paper.

5 Unbalanced forces should be at a minimum.

6 Good cutting and mechanical durability are desirable at high forward speeds (perhaps up to 10 mph).

In this paper the cutting action of the conventional mower is analyzed and additional examples are included to show how this method of analysis can be applied to other designs. The two examples used involve a guardless mower with two reciprocating knives, designed by Russian engineers. Bosoi (2)* describes the method used in designing this mechanism, gives dimensions of the blades for his design, and includes a discussion of test results with the machine. One analysis presented for the double-knife mower is for a 1½-in stroke and high crank speed (according to Bosoi's design), and the other is for the same mechanism with a 3-in stroke (two cuts per stroke) and a lower speed.

Definition of Terms and Symbols. Since some of the terms used in the following discussion are not entirely self-explanatory, the following list of definitions and symbols should be helpful; most of these items are also identified in Fig. 1:

W = width of knife blade or ledger plate, in inches; subscripts k, p, f, and r refer to knife, ledger plate, front, and rear, respectively

d = depth, from front to rear, of the cutting portion of the blades, in inches

β = slope of cutting edge with respect to direction of forward motion, in degrees; subscripts k and p refer to knife and ledger plate, respectively

θ = degrees of crank rotation beyond start of stroke

X = knife displacement from start of stroke (in inches) at any crank angle, θ

X_t = total knife stroke, in inches

*Numbers in parentheses refer to the appended references.

X_b = pitch or spacing of blades on knife, in inches

Y = forward travel from start of stroke (in inches) at any crank angle, θ

Y_t = *feed rate*, in inches of forward travel per stroke

α = *friction angle* (in degrees), which is the angle that the resultant force of the stalk against the cutting edge makes with the normal to the cutting edge when the stalk starts to slip along the edge; tan α is the coefficient of friction; subscripts k, p, f, r, and a refer to knife, ledger plate, forward slipping, rear slipping, and slipping across front edge, respectively

V = knife velocity, in feet per second

N = crank speed, in revolutions per minute

Cutting graph is basically a plot of knife displacement vs. forward travel, with stalk paths superimposed.

Slip line (knife, knife-front, or ledger) is a line on the cutting graph representing the direction in which stalks are deflected when slippage along the contact edge is occurring. The slope of the knife slip line, for example, is $\alpha_{kr} + \beta_k$.

Cutting line represents the intersection of the two cutting elements, plotted on the cutting graph.

Stalk path is a line on the cutting graph that represents the path over which a stalk is deflected as it is moved toward the cutting point.

Friction Angles for Stalks Against Blades. In order to determine the paths followed by stalks of hay as they are pushed toward the cutting line by the cutting edges, it is necessary to know or assume the friction angle (α) between the stalks and the cutting edges.

Bosoi (1) constructed a laboratory setup by which friction angles or the angle of pinching between two blades could be measured. The two blades were mounted one above the other (as in a mower) so that they could be pushed slowly together with a stalk between them. Various included angles between the cutting edges were then tried to determine the maximum angle at which cutting would occur without the stalk slipping out. When the stalk was suspended by a thread, the included angle thus determined represented twice the friction angle. In other tests, stalks were clamped at various distances below the blades to represent different heights of cut. The included angles, or angles of pinching, were then greater than the double friction angle because of the bending resistance of the stalk along the direction perpendicular to the blade displacement.

Results presented by Bosoi in his paper (1) are summarized in Table 1. In establishing the maximum included angle which should be used between two cutting edges, it is desirable to take the values given for suspended stalks (infinite cutting height). However, in practice somewhat larger angles would usually be satisfactory, as indicated by the larger angles of pinching at the lower cutting heights. A typical value for the included angle on a conventional mower is about 38 deg. Bosoi's data in Table 1 indicate that cutting of wheat straw with a conventional mower at heights greater than about 8 in would be marginal when using smooth blades and serrated ledger plates.

In determining when stalks will slip along the cutting edges as they are being pushed toward the cutting line, the double angles given for suspended stalks are used as a basis for α. Bosoi (2) suggests using α = 17 deg for smooth-edged blades and 25 deg for serrated edges. Because of the shape of serrations on the ledger plates of a conventional mower, stalks slide rearward along the ledger plates more easily than to the front. Consequently a value of α_{pr} = 20 deg was assumed in plotting stalk paths.

Construction of Cutting Graph for Conventional Mower. The cutting action was analyzed for feed rates of 1½ in, 2 in, and 3 in forward travel per stroke. The cutting graph for the 3-in feed rate is shown in Fig. 1. Stalks originating in the shaded area MPRTBDFGM will all be cut on the line EF as the knife moves from left to right.

TABLE 1. FRICTION ANGLES OF STALKS OF WHEAT AND QUACK GRASS AGAINST VARIOUS TYPES OF CUTTING EDGES

	Angles of pinching (degrees) at various cutting heights				
	2 in	4 in	5.9 in	7.9 in	Stalks suspended
Stalks of wheat straw ([illegible] in diameter)					
Two blades with smooth edges	47	41	34	[illegible]	27-34
Two blades with upper serrations	[illegible]	[illegible]	63	53	34-40
Two blades with under serrations	141	133	125	112	66-84
Smooth blade and serrated ledger plate	[illegible]	[illegible]	47	49	[illegible]
Blades with milled upper serrations	..	..	..	..	36-42
Blades with milled under serrations	..	..	..	..	47-55
Stalks of quack grass					
Two blades with smooth edges	51	[illegible]	43	42	37-44
Two blades with upper serrations	122	110	106	90	65-75
Two blades with under serrations	164	141	125	116	84-90
Smooth blade and serrated ledger plate	88	[illegible]	53	47	40-45
Blades with milled upper serrations	..	..	..	..	35-40
Blades with milled under serrations	..	..	..	..	66-75

Note 1. Information in this table is from test results reported by Bosoi (1).

Note 2. Values given are maximum included angles between cutting edges at which stalks would be cut rather than slipping out. Values with stalks suspended (corresponding to infinite cutting height) represent double friction angles, or 2α.

The forward limit of area covered by the stroke under consideration is defined by ledger slip lines BD and FG which are drawn at a slope represented by $\alpha_{pr} + \beta_p$, and by DF, which is the path of the front leading corner of the blade. Stalks originating along BD and FG are deflected by the guards and ledger plates to points D and G, and all stalks behind DF are pushed to the cutting line by the blade. Similarly all stalks originating below the line MPRT will have been cut in the preceding stroke.

Cutting will begin when the front center of the blade is at point 3, such that the rear corners of the blade and ledger just come together. At this point the knife displacement is

$$X_3 = X_t - \frac{W_{kr} + W_{pr}}{2} \qquad [1]$$

When cutting finishes, at point 4,

$$X_4 = X_t - \frac{W_{kf} + W_{pf}}{2} \qquad [2]$$

Assuming sinusoidal motion, the corresponding values of θ_3 and θ_4 can be calculated from the equation

$$X = \frac{X_t}{2}(1 - \cos\theta) \qquad [3]$$

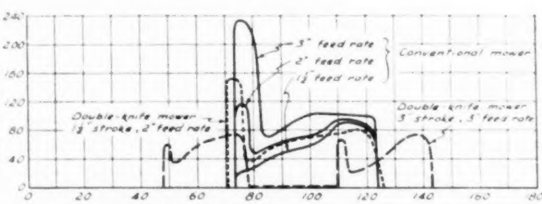


Fig. 2 Calculated cutting force in the direction of knife travel, as a function of crank angle. Cutting forces are based on 60 per cent of a total equivalent draft of 80 lb per ft of mower width, i.e., 48 lb per ft used in the actual cutting process. For a conventional mower with 3-in feed, assumed 60 per cent of A_0 (area crowded ahead) was cut in first 10 per cent of cutting $\Delta\theta$ and 40 per cent in second 10 per cent. For all others, assumed A_0 was cut in first 10 per cent of cutting $\Delta\theta$

TABLE 2. COMPARISON OF FACTORS RELATED TO CUTTING, FOR FIVE MOWER ARRANGEMENTS

	Conventional mower, 3-in guard spacing			Guardless mower with 2 active knives and 3-in blade spacing	
Knife stroke, inches	3	3	3	1½	3(a)
Feed rate, inches per stroke	1.5	2	3	2	3
Per cent of stroke with cutting	41	41	41	46	46
Per cent of crank rotation with cutting	28	28	28	31	35
Cutting force, pounds per foot of cutter bar(b)					
Average during cutting period	55	77	116	70	53
Maximum during first part of period	20	110	235	150	65
Maximum during rest of cutting	90	95	100	100	75
Area A_0, in per cent of total area(c)	0	9	25	17	6
Maximum stalk deflection, inches					
Rear stalks	0.7	1.3	2.4	1.8	0.9
Side stalks	1.2	0.9	1.2	1.4	1.4
NOTE: The following figures apply only for the assumed speeds:					
Assumed speed, rpm	1000	900	900	1320	880
Corresponding forward speed, mph	2.8	3.4	5.0	5.0	5.0
Maximum knife velocity, ft per sec	11.9	11.9	11.5	8.7	11.5
Initial cutting velocity, ft per sec(d)	11.2	11.2	11.2	16.8	19.8
Final cutting velocity, ft per sec(d)	10.5	10.5	10.5	15.6	18.0

(a) Blades cross over at midpoint of stroke, giving two cutting zones per stroke.

(b) Assumed total equivalent draft of mower = 80 lb per ft of width, with 65 per cent of this being used for the actual cutting process.

(c) A_0 is area crowded ahead by the rear of the knife before cutting starts (see graphs).

(d) Velocity of one cutting element with respect to the other, at start or finish of cutting portion of the stroke. For the double-knife mower, the relative velocity is twice the knife velocity.

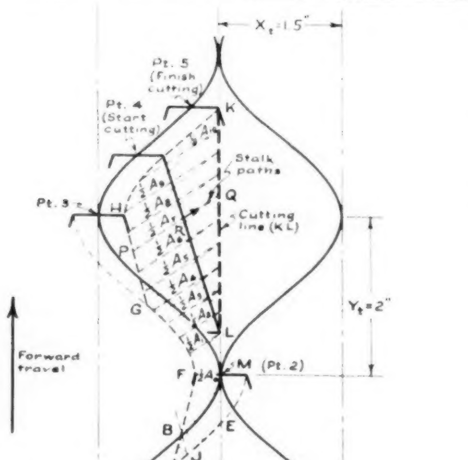


Fig. 3 Cutting graph for guardless mower with two reciprocating knives (smooth blades), a stroke of 1½ in, and a feed rate of 2 in. Paths of cutting elements and stalks being deflected to the cutting line are plotted with respect to the ground. Stalks originating in the shaded area and those from an adjacent image area to the right of EK are all cut along line KL.

and knife velocities at the start and finish of cutting may be obtained from

$$V = \frac{\pi}{720} X_t N \sin\theta \qquad [4]$$

where V is in feet per second, X_t is in inches, and N = rpm.

For a mower with the dimensions indicated in Fig. 1, $\theta_3 = 73$ deg and $\theta_4 = 123$ deg. The cutting line, EF, was determined by dividing the increment, $\theta_4 - \theta_3$, into ten equal parts, calculating the knife displacement for each intermediate θ and then determining by geometry the corresponding points of intersection of the two cutting edges and plotting these points on the cutting graph. EF is not quite a straight line because the relation of knife displacement to forward travel is not quite constant during the cutting period. The use of equal increments of θ in plotting the cutting line simplifies the subsequent analysis.

Stalk paths were drawn from each of the points used in plotting the cutting line, as shown in Fig. 1. These path lines were constructed on the premise that a stalk in contact with a moving edge will follow the path of the contact point except when the slope of the line from the point of origin of the stalk to this point of contact exceeds the slope of the slip line for that edge; then the stalk will slide along the edge to maintain the slip-line slope. When a stalk is in contact with a moving edge, the two principal forces pressing it against the edge are the bending resistance of the stalk and the inertia force of the stalk, the first acting toward the point of origin of the stalk and the other acting opposite to the direction of stalk acceleration. When a stalk is sliding along the moving edge, both of these forces act along the slope of the slip line. When the resultant of the two forces is at a slope less than that of the slip line, the stalk does not slide, but follows the path of the contact point.

Consider stalk path, J'L'V', which represents the path of stalks cut by point U' of the knife edge at point V' on the cutting line. J'L' is drawn tangent to the plotted path of point U', with a slope equal to that of the knife slip line. Stalks originating along J'L' will slip on the knife edge, following the path J'L' until L' is reached, and will thereafter move with the knife to point V' without slipping. Stalks originating along L'V' will not slip on the knife.

Now consider a more complex stalk path, HJLV. K is the spot at which point U on the knife cutting edge leaves the ledger plate, and HK is drawn at the slope of the ledger slip line. JL is at the slope of the knife slip line and is tangent to the path of point U. Stalks originating along HJ will be deflected to K by the ledger plate. They will then be moved by the knife along KL without slip, because the slope of the line between any point on HJ and any point on KL cannot exceed the knife slip slope represented by JL. Conversely, stems originating along JK will slip before they reach point L. Thus the correct stalk path includes HJL and not HJKL; all stalks originating along HJLV are deflected to point V where they are cut by point U on the knife cutting edge. Stalks from ZV are deflected by the guard and ledger plate and also cut at V.

Since the stalk paths were drawn through points representing equal increments of θ on the cutting line, the areas between adjacent stalk paths represent land areas cut during equal increments of θ. These areas are indicated in Fig. 1 by A_1 to A_{10}, inclusive. It will be noted that there is also an area A_0 which must be crowded forward in order to be cut by the rear portion of the knife. In Fig. 1, A_0 represents 25 per cent of the total area cut per stroke. Such a large A_0 is undesirable because of the bunching effect at the rear of the knife with the resulting large cutting force required at the start of cutting, and because of the excessive stalk deflection involved.

If the feed rate for the conventional mower is reduced to 1.55 in per stroke (which value was determined analytically), points Q and E (Fig. 1) will coincide and A_0 = O. With a 2-in feed rate, A_0 = 9 per cent of the total area (determined from

graph similar to Fig. 1). With a horse-drawn mower a typical feed rate would be about $1\frac{3}{4}$ in and A_0 would be small. With tractor mowers, however, feed rates as high as the 3 in represented by Fig. 1 are not uncommon (for example, 5 mph at 880 rpm).

Deflection of Stalks. Once the cutting graph has been constructed, the maximum stalk deflection can be determined by direct measurement. In Fig. 1 the maximum deflection of the rear stalks is from M (point of stalk origin) to E (point of cutting), a distance of 2.4 in. The maximum deflection of side stalks is from B to F, a distance of 3.2 in. Corresponding deflections for the same mower with a feed rate of $1\frac{1}{2}$ in instead of 3 in are 0.8 and 2.8 in. Thus, with the conventional mower, side deflection is generally more serious than deflection from the rear. For a cutting plane 2 in above the ground and a maximum stalk deflection of 3 in, the theoretical range of stubble lengths (from vertical stalks) would be 2 to 3.6 in. In addition, excessive deflection causes the stalks to have more of a tendency to slip forward out of the cutting unit and be cut higher or missed entirely (3).

Estimating Cutting Force as a Function of θ. If one assumes that the actual cutting energy required for a given increment of θ is directly proportional to the land area from which stalks are cut during that increment, the individual areas indicated on the cutting graph can be used in determining cutting force as a function of θ.

It is estimated that 60 to 75 per cent of the total power input to a mower is used in the actual cutting process, the remainder being required to overcome knife friction and other power-transmission losses, the rolling resistance of the supporting wheels, the frictional drag of the cutter bar on the ground and stubble, and other similar losses. In Agricultural Engineering Data 2 (4), the total equivalent draft of a mower is given as 60 to 100 lb per ft of width. If one takes the average value of 80 lb and assumes that only 60 per cent of the total energy is used in cutting, the equivalent draft for cutting would be 48 lb per ft of width or 4 lb per in of width. Thus, considering a forward travel of 1 in, the cutting energy required is 4 in-lb per sq in of land area.

The average cutting force exerted in the direction of knife displacement during any increment of time or θ is

$$F = \frac{E\ (\text{sq in of land area cut during } \Delta\theta)}{\Delta X_k + \Delta X_p}$$

where ΔX_k and ΔX_p are the lateral movements of the two cutting units (in opposite directions) during $\Delta\theta$, and E is the cutting energy required per square inch of land area. With the conventional mower, $\Delta X_p = 0$, but with a double-knife mower, $\Delta X_p = \Delta X_k$.

If the areas measured from the cutting graph for one stroke are used, E is taken as 4 in-lb per sq in and F is to be expressed as pounds per foot of width. Then

$$F = 4 \times \frac{12}{X_b} \times \frac{\Delta A}{\Delta X_k + \Delta X_p} \qquad [5]$$

where ΔA is the area (such as A_3 in Fig. 1) cut during a given $\Delta\theta$, and X_b is the blade spacing on the knife. For a complete stroke, the area cut per blade is $\Delta A = X_b \times Y_t$. Thus, from equation [5], the average cutting force (pounds per foot of width) during the entire cutting portion of the stroke is

$$F_{avg} = 4 \times 12 \frac{Y_t}{\Delta X_k + \Delta X_p} \qquad [6]$$

When the feed rate is large enough that a rear area A_0 exists, some assumption must be made as to how much of the rear part of the knife is used in cutting these bunched stalks. Based on some rough measurements in fields of barley, alfalfa, and pasture grasses, it is estimated that the cross-section area occupied by a group of stalks bunched together for cutting would be not more than 1 to 2 per cent of the land area on which the stalks originated.

In Fig. 1, A_0 represents 2.24 sq in of land area and A_1 is 0.33 sq in (measured with planimeter). Thus the stalks from $A_0 + A_1$ could be crowded into a cross-section area of about 0.03 sq in. If they were all to be cut by the rear section (1/10) of the knife blade, the thickness of the bunch on the blade would be a little more than $\frac{1}{8}$ in. For many mowed crops the entire bunch represented by the area A_0, even in this example of extreme crowding, would average only a few stalks per knife section. Conservatively, one might estimate that for the conditions of Fig. 1, 60 per cent of A_0 would be cut by the rear one-tenth of the blade and 40 per cent by the next one-tenth of the cutting edge. For all other examples treated in this paper, A_0 was considerably smaller and was assumed to be cut entirely by the rear one-tenth of the blade.

Curves showing the calculated cutting force as a function of θ for the three feed rates with the conventional mower, as well as for two conditions with the double-knife mower, are included in Fig. 2. Note that for the conventional mower with 3-in feed rate, the large A_0 results in a high force at the beginning of the cut (235 lb per ft of width), whereas with a feed rate of $1\frac{1}{2}$ in there is no A_0 and the force gradually increases during the cutting interval. During the last quarter of the cutting interval there is not much difference between the forces for the three feed rates.

It should be kept in mind that these curves do not represent the net force at the knife head. Other forces which contribute

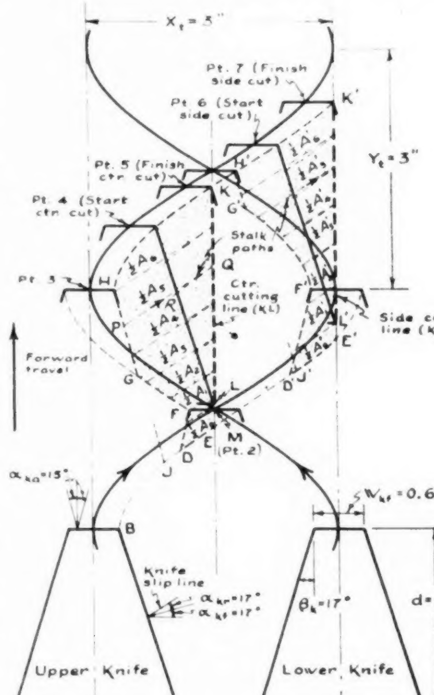


Fig. 4 Cutting graph for guardless mower with two reciprocating knives, a stroke of 3 in (two cuts per stroke), and a feed rate of 3 in. Paths of cutting elements and stalks being deflected to the cutting line are plotted with respect to the ground. Stalks originating in the two shaded areas and in two adjacent image areas to the right of those shown are cut along the two lines KL and K'L'.

to the knife-head force but are not considered in this paper are the inertia force of the knife and the frictional force between the knife and its supports. For example, a 10-lb knife following a sinusoidal displacement pattern with a stroke of 3 in and a crank speed of 1000 rpm would have a peak inertia force of 428 lb (at $\theta = 0$); the estimated *peak* cutting force for a 7-ft conventional mower with a 3-in feed rate (from Fig. 2) would be about 1600 lb, or nearly four times as great as the inertia force. Fortunately, this peak cutting force is of short duration and does not involve a reversal of force. However, the *average* cutting force for this mower is about 800 lb during the 50-deg cutting period. Since the cutting force is practically zero during the remaining 130 deg of the stroke, vibration effects of considerable magnitude should be expected from this cyclic variation of cutting force.

Analysis for Guardless Mower with Two Reciprocating Knifes. Fig. 3 shows a cutting graph for the guardless mower described by Bosoi (2). The dimensions used are those given in this paper. He recommends operating this mower at about 1300 rpm. A feed rate of 2 in per stroke was selected for the present analysis so that direct comparison at a given forward speed could be made with the 3-in feed rate of the conventional mower and a reasonable crank speed.

With the guardless mower, a new problem is introduced, namely, the possibility that stalks may not slide off the front edge of the blade. In Fig. 3, line FD is drawn at the slope of the knife-point slip line, assuming $\alpha_{ko} = 15$ deg. As the knife moves from point 1 to point 2, stalks in the path of the front edge will be pushed ahead. By the time point 2 is reached, any stalks originating to the left of FD will have slid off past the left front corner, but stalks originating in the area DFMED will still be on the front edge. As the knife moves from point 2 to point 3, those stalks originating to the left of knife-point slip line HJ will slide off past the right front corner. If the feed rate is too great, some stalks might not slide off of either corner but be pushed ahead until they went beneath the blade without being cut.

Thus in the example of Fig. 3, individual stalks in the area BDJ would theoretically never slide off the front. In actual practice, however, interference of other stalks might help them in moving off, and the effective friction angle might be less than the 15 deg assumed. Using a narrower front width of blade would help the situation, but would also reduce the cutting velocity at the finish of the cut. This narrowing will occur automatically as the blades wear and are sharpened.

The area cut during one stroke is the shaded area DFGHKE plus an equal and opposite area to the right of KE. In this particular cutting graph, all stalk paths (such as PQ) are drawn at the slope of the knife slip line, because the paths (such as RQ) of all points on the knife-edge exceed this slope even at the cutting line.

An additional analysis of Bosoi's mower was made, assuming the same blade dimensions and spacing, but using a 3-in stroke and a feed rate of 3 in per stroke. This would give two cuts per stroke, as indicated in Fig. 4. Half areas for each of the two cuts are indicated by the shaded areas. The preceding discussion of Fig. 3 applies directly to Fig. 4, except that FD and HJ do not cross for the center cut and there is no area from which stalks are likely to remain on the front edge of the blade.

Curves of cutting force for the two arrangements of the double-knife mower are included in Fig. 2. In addition, various factors are compared for all five combinations in Table 2. The conventional mower with 3-in feed rate and the two combinations with the double-knife mower, are directly comparable at a forward speed of 5 mph when the crank speed is 1320 rpm for the double-knife mower with 1½-in stroke and 880 rpm for the other units. Since the inertia force of a given reciprocating mass varies as the square of the speed and the first power of the stroke, these forces would be nearly the same in all the setups.

The double-knife unit with 1½-in stroke and 2-in feed rate has a fairly large A_0 area, but is considerably better than the conventional mower with 3-in feed in regard to stalk deflection, cutting velocities, and initial cutting force.

The double-knife unit with 3-in stroke and 3-in feed rate has a small A_0 area, low peak and average cutting forces, small stalk deflections, and high cutting velocities. This setup, with its two counter-balanced knives, could undoubtedly be operated at crank speeds considerably greater than the 880 rpm assumed in this comparison, and the feed rate might be increased to perhaps 4 in without any great sacrifice in quality of cutting. Even at only 1000 rpm the 4-in feed would represent a forward speed of 7.6 mph.

A similar analysis could be applied to other proposed or existing designs in which cutting is accomplished by the intersection of two cutting edges. For example, the action of a unit in which opposite-moving blades were attached to a belt or chain would be similar to that shown in Fig. 4, except that the knife paths would be intersecting straight lines instead of sine curves.

It is realized that the foregoing analysis is based on idealizations, such as the absence of interference between stalks against the cutting edges and the assumption that the stubble is growing vertically. However, such an analysis should be worth while and useful in comparing designs and predicting the influence of the various factors upon the cutting performance.

SUMMARY AND RECOMMENDATIONS

The cutting actions of a conventional mower and of a guardless mower with two reciprocating knives are analyzed in this paper, but no attempt is made to consider mechanical details or the effects of unbalanced reciprocating parts.

With the conventional mower the maximum deflection of side stalks is excessive even when the feed rate (forward travel per stroke) is only 1½ in. With a 3-in feed rate (a condition frequently encountered in tractor mowers), the deflection of stalks from the rear is also excessive, and stalks from about 25 per cent of the land area must be crowded ahead by the cutter bar before being cut. This results in a large cutting force at the beginning of the cut. With a 1½-in feed rate, none of the stalks are crowded ahead by the cutter bar of the conventional mower. The double-knife setup with 3-in stroke and two cuts per stroke appears to be considerably better than the conventional mower or the double-knife unit with 1½-in stroke.

The following factors, relating to the cutting action, should be considered in designing a cutting mechanism or evaluating an existing design:

1 On the basis of data reported by Bosoi (1), the included angle between the cutting edges should not exceed about 35 deg for smooth edges, 50 deg for serrated edges, or 40 to 45 deg for a combination of smooth and serrated edges.

2 Excessive deflection of stalks by the machine prior to cutting results in stubble of non-uniform length and may cause stalks to slip out without being cut. Excessive deflection from the rear also accumulates a "bunch" of stalks at the rear of the blade prior to cutting, which requires a large, suddenly applied cutting force at the start of the cutting period.

3 In order to minimize deflection of stalks from the rear, it would seem desirable to limit the feed rate to a maximum equal to about two-thirds of the relative motion of the two cutting elements per stroke. Thus, for a double-knife setup with 3-in stroke, the limit would be 4 in of forward travel per stroke.

4 A short stroke (such as 1½ in) minimizes side deflection of stalks but requires high crank speeds to avoid excessive feed rates at the higher ground speeds desired for present-day tractor mowers. One possible compromise is to use a longer stroke (such as 3 in) and lower crank speed to minimize inertia forces (which vary with the square of the speed and the first power of the stroke), and then obtain two cuts per stroke by doubling the number of guards or using two reciprocating knives which cross over (as in Fig. 4).

5 The average cutting force during the cutting portion of the stroke may be at least as great as the maximum inertia force of the knife, and should be expected to cause vibration effects of considerable magnitude in a single-knife machine. For a given mower the average cutting force is directly proportional to the feed rate. *(Continued on page 704)*

Engineering Appraisal of Farm Mechanization

By Harry B. Walker
FELLOW ASAE

FOOD and raiment are basic necessities of man. The methods by which man has sought and produced them are closely related to his social progress and economic status, otherwise known as living standards. The land area of the world is for all practical considerations static, and, likewise, the natural environments over the land do not change perceptively from generation to generation. Under these relatively fixed conditions the world's population has expanded to over 2.4 billions. This has required upon man's part some organization of supply sources of these essentials.

This organizational development has been evolutionary to a degree, having its primary origin in the instinctive impulses of man for food and shelter, out of which pastoral types of agriculture were eventually evolved by nomad peoples. Later more static and highly organized types were evolved, such as fallow cultivation, legume production and composting, crop-rotation systems, and, as in modern times, specialized scientific crop production. All of these various forms of organization for food and fiber production by man may be found in the world today, thus supplying examples of man's progress, or lack of it, in securing these commodities for human comfort and existence.

These practices are designated by the term agriculture, which is, broadly speaking, both the art and science of the production of plants and animals useful to man, including to a variable extent the preparation of these products for man's use and their disposal by marketing or otherwise. The practice of agriculture is inherently basic in character, because it deals with the primary essentials for human existence. It comprises the production and distribution of raw materials for food, clothing, shelter, and in more highly developed areas, various crop materials for industrial uses.

Progress in agriculture throughout the world is not uniform. The United Nations (1)* report that "two-thirds of the people of the world are fighting a losing battle against poverty, hunger, and ignorance," and that one-third is progressing constantly toward a higher standard of living. The North American continent, for example, with one-tenth of the world's population produces 45 per cent of the world's income, while Asia, with 50 per cent of the world's population, produces only 11 per cent. It is in North America, and particularly in the United States and Canada, that technological agriculture has been widely developed and accepted. Yet even on this continent developments are comparatively recent, so there is little historical evidence to indicate how enduring such modern methods may be in a complex world society.

There are many facets to this problem, such as land availability, natural resources, human initiative and incentive, forms of government and the like, but it is more than a coincidence that progress where it is found has paralleled technological advances in the physical and biological sciences.

On this occasion, engineers are celebrating a century of organized technological progress in this nation. It is fitting and proper, as a matter of record, that some review should be made of the engineering progress of this nation in our oldest industry—agriculture—with reference to its effect on the economic and social progress of our people.

A hundred years ago agriculture was an art. Engineering as such had no recognized place in farming, yet the mechanical genius and inventive skill of man had already made worth-while contributions to farm progress. The cotton gin, the grain thresher, the reaper, and the steel plow were already important aids to agricultural production. These were products of the inventive genius of man, rather than the products of analytical technology. Already the steam engine and electric motor had been developed, but their applications to farm practices had not been conceived.

Thus a century ago the germ of mechanical development in agriculture was planted, but few if any could visualize how this was to influence the economic and social progress of our continent. The inherent initiative, imagination and originality of our people coupled with a form of government which has encouraged free enterprise have contributed much to farm mechanization progress and the advancement of engineering and agricultural technology. We should bear in mind, however, in making comparisons with other nations, the favorable circumstances of land areas and natural resources we have enjoyed.

Usher (2) in his book entitled "A History of Mechanical Inventions," points out that scientists, inventors, and explorers are in many ways at the base of transformation of social life, because they all do creative work. Scientists discover new truths and relationships, inventors seek completed ideas, and explorers seek new areas and resources. These contribute to scientific progress and technological change, thus furnishing the account of the most important factors in the active transformation of environment by human activity. In this, Usher explains there is a certain sequence of change. First, we have the contributions of the scientist, inventor, and explorer, which contribute to technological change and development; secondly, this is followed by certain consequences due to the exploitation of such new knowledge, and, thirdly, the causes and effects of exploitation must be adjusted to the laws and customs of the people. Out of all of this are evolved changes in the mode of life of people, thus contributing to social and economic change.

In agriculture, human energy plays an important part. The more primitive the production methods, the more important human energy becomes in producing the essentials for human existence. There is abundant evidence of this throughout the world. A single comparison, however, suffices to indicate the validity of this statement. In the United States only about one-third of our total population is classed as rural, while in China about 75 per cent may be so classed. Our nation's progress in agriculture has been directly related to our ability to substitute other forms of energy for human effort.

During the last century, in this country great technological influences have been at work to accelerate such changes. One of the important factors contributing to this has been the establishment of land-grant colleges, or colleges of agriculture and mechanic arts. These institutions authorized by the Morrill Act of 1862 and followed in 1887 by the Hatch Act establishing agricultural experiment stations have had an important influence upon the development of technology applicable to the production, distribution, and marketing of the products of the soil, as well as the living environments of those tilling the soil. This technology includes both the physical and biological sciences and in this respect engineering progress in agriculture cannot be separated from the biological advancements relating to farming. Technology coupled with invention and scientific discovery have made the farm workers of this nation among the most productive in the world.

A century ago about 64 per cent of this nation's labor force was engaged in agricultural pursuits. Fifty years later this had dropped to about 37 per cent, while today it is about 14 per cent. Only about 15 per cent of our population today is classed as farm, yet the nation's families are fed and clothed as well as any in the world and much better than most. The development and use of the grain thresher, cotton gin, steel

An address before a special meeting of the American Society of Agricultural Engineers held in conjunction with the Centennial of Engineering Convocation at Chicago, Ill., September, 1952.

The author: HARRY B. WALKER, professor emeritus of agricultural engineering, University of California. Mr. Walker is a past-president of ASAE, and was the 1950 recipient of the John Deere Gold Medal awarded by the Society.

*Numbers in parentheses refer to the appended references.

plow and the reaper were the introductory machines, which later led to more and more mechanical devices destined to take much of the labor load from farming and make it available for other industrial pursuits.

These changes in labor efficiency have always been associated with power utilization. Up to 100 years ago man labor was the chief productive energy in farming throughout the world. In this country, however, 100 years ago the farmer had already recognized the potentialities of animal power as applied to crop production, and he began to devise ways and means of utilizing this form of energy. In this connection, however, it is important to remember that at that time our nation had an abundance of land and limited markets for farm products. This abundance of new, fertile land was stimulating to the initiative and imagination of a pioneer people who could readily recognize the advantages of utilizing the land itself to supply a supplementary source of energy for productive purposes useful to them.

ANIMAL POWER HAD DEFINITE LIMITATIONS

Thus the utilization of animal power not only increased output per worker, but products of the land (feed) served also to provide the fuel for this energy. For many years animal power dominated agricultural production and satisfied the farmer also, because he was able to proceed from the simple single-bottom plow to the more complex gang plow, and from single animal hitches up to thirty or more.

The peak of animal-power utilization for agriculture was reached only about three decades ago. It was the predominating productive power for American agriculture for nearly three-fourths of the past century. This form of power, however, did not fully satisfy the farmer who now had more time to think and plan production. The science of agriculture as developed in agricultural colleges and experiment stations, and brought to the farmer by extension methods, made him conscious of the timeliness and speed of operations in crop production. Moreover, industrial progress in urban areas competed for his labor, and created a growing demand for the crops he produced to feed his draft animals.

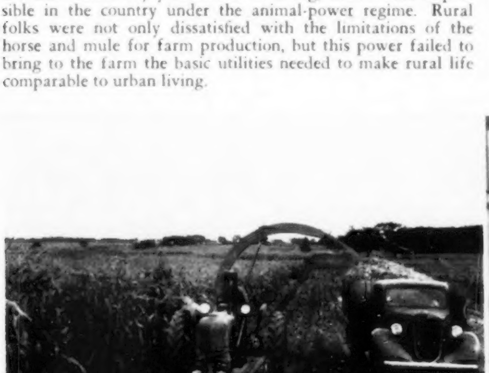
Furthermore, while animal power had greatly reduced field labor, it did very little to relieve the burdens of rural housekeeping and farm chore work. Animal power being essentially linear power was difficult to translate into rotary forms, so it contributed little to lightening the burdens of rural housekeeping. In the meantime, industrialization of our nation proceeded and urban populations increased. Those who lived in the cities could enjoy standards of living, which were impossible in the country under the animal-power regime. Rural folks were not only dissatisfied with the limitations of the horse and mule for farm production, but this power failed to bring to the farm the basic utilities needed to make rural life comparable to urban living.

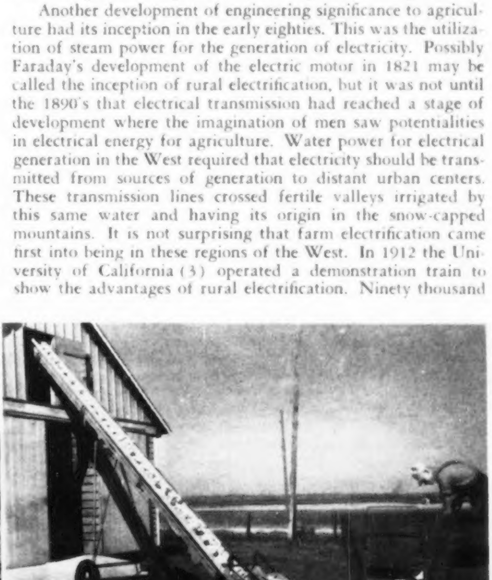
Soon after the beginning of the last half of the 19th century our first oil wells were discovered (1859). As a discovery this seemed to have no importance to agriculture other than to afford a supply of fuel (kerosene) for lamps. However, in the last quarter of the past century the Otto-cycle engine came into being and these two things—discovery of oil and the invention of a practical internal-combustion engine—were destined to play an important role in the future mechanization of agriculture. The steam engine had appeared earlier and it was used successfully for stationary operations like grain threshing, but it had only limited applications for mobile farm operations, due to its weight, cost, and fuel characteristics. But it created in the farmer a desire for mobile mechanical power. The advent of the automobile further stimulated this desire. By 1895 some attempts had been made to develop a mobile farm power unit equipped with an internal-combustion engine. Subsequent developments came rapidly due to the heavy food demands occasioned by World War I, labor shortages, and the need to conserve for human requirements the feeds used by work animals. The internal-combustion mobile power unit became known as the tractor. By 1918 there were over 180 so-called tractor manufacturers.

CONTROL OF MORE POWER INCREASED RATE OF DOING WORK

These developments had a tremendous effect upon farmers and their conception of the potentialities of mechanized agriculture. The control of more and more power by the farm worker increased the rate of doing work and provided the potential for timely operations. It also tended to minimize the hazards of weather thus helping the farmer to do his farming as science, developed through the experiment station, indicated it should be done and at the time it should be accomplished. By the end of World War I, the animal-power epoch had passed its peak and the basic elements for a mobile farm power plant were proven. This marked the beginning of the truly technical and practical impact of engineering science on agriculture.

Another development of engineering significance to agriculture had its inception in the early eighties. This was the utilization of steam power for the generation of electricity. Possibly Faraday's development of the electric motor in 1821 may be called the inception of rural electrification, but it was not until the 1890's that electrical transmission had reached a stage of development where the imagination of men saw potentialities in electrical energy for agriculture. Water power for electrical generation in the West required that electricity should be transmitted from sources of generation to distant urban centers. These transmission lines crossed fertile valleys irrigated by this same water and having its origin in the snow-capped mountains. It is not surprising that farm electrification came first into being in these regions of the West. In 1912 the University of California (3) operated a demonstration train to show the advantages of rural electrification. Ninety thousand





The applications of J. I. Case equipment pictured here are typical of the evolution of the use of power and improved machines on American farms in the past quarter century

people visited this demonstration train. By 1920 approximately one-third of the farms of California were using electricity. Water pumped by electricity irrigated nearly 1½ million acres of the state's farm lands by this time. This engineering development in agriculture, while rapid in the western costal areas, did not reach its full fruition for the country as a whole until the nation decided to subsidize its extension to farms through the Rural Electrical Administration organized in 1935.

Electricity, however, did more than any other form of power to advance the standards of rural living. It gave to the housewife a form of energy so versatile in nature that it could be used for heat, power, light and communications, thus providing in one form a type of energy to make possible all of the advantages of modern appliances for the isolated farm home. In addition, it has brought to the farm a form of energy adaptable to farm chore work, farm processing, domestic and irrigation pumping, farm storage, and crop preservation.

The contributions of the scientist, inventor and discoverer, as reflected in the discovery of petroleum, the development of the internal-combustion engine and related farm equipment, and the transmission and use of electricity with related mechanical devices for its use, have provided the means for extensive mechanization of the farms and homes of our land. These have made our farmers among the most productive in the world, and have provided for our farm families the potential mechanical devices required to make farm life the most attractive and healthful of any known rural area.

In the over-all picture, our nation has become industrial through the mechanization of its farms and factories. Farming under engineering development has fallen heir to industrial methods and analysis. The farmer of today is concerned with volume production of high-quality products at low cost. He too must consider and be concerned with break-even points. He is no longer concerned with mere subsistence. He has a much greater responsibility, for today only about 15 per cent of our total population is now on farms. These folks must produce not only for themselves, but far more important they carry the responsibility of producing in excess enough food and fiber for the 85 per cent not on farms, but living in cities and hamlets to provide with similar efficiency, manufactured and processed goods and services for the nation.

Produce in Abundance Is Farmer's Responsibility

So it is that science with engineering in agriculture has changed our nation from rural to urban, from agricultural to industrial, and from a population representing a farm majority to a population with a farm minority. These changes have greatly increased the stature of farmers, by placing upon them the responsibility of producing in abundance and at reasonable cost the raw-product needs for an expanding industrial population. Furthermore, they face the necessity of maintaining at a high level the soil resources of our nation.

This change is shown by the accompanying graph (4) indicating the percentage distribution of the labor force of this nation in non-agricultural and agricultural pursuits for the period 1850 to 1950, with extensions to 1970. For the last 70 years farm workers by percentage have continued as a declining minority. This has been offset by the productive effort of the farm worker. Barger (5) and Landberg in making a study of output per farm worker, 1870-1939, and using 1890 as 100 for total output, employment, and output per farm worker, gives the following corresponding figures for 1940: total output 378, employment 134, and output per farm worker 284. Farm productive efficiency, moreover, has made phenomenal progress in the past decade. Farm output per man-hour since 1940 is estimated to have increased around 50 per cent above the 1940 figure.

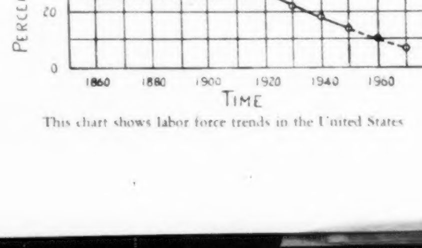
Thus agriculture during the past 100 years has evolved from the pioneering mode of life, with subsistence an important factor, into a productive industry which utilizes power and machinery as instruments of management in efficient production. As numbers in farming have decreased relatively, factors of science and management have increased. Today the farm manager commands the respect of intelligent, informed people. Due to the continuing minority of farmers, the public is less able to become acquainted with their changing environments and practices. So today the farmers have a growing public relations problem. Many people think of farming as it was several decades ago rather than as a pivotal dynamic industry of increasing importance in our national welfare.

Farming in this country is an industry which in 1950 utilized over 3.6 million tractors, more than 2.2 million trucks and 4.2 million automobiles. Hence farmers are good customers of heavy manufacturing, petroleum, tire and other industries. As an example, the average farm of today (6) has 52 tires on its cars, trucks, tractors, combines, and other mobile equipment, thus making the agriculturist the rubber industry's biggest potential tire customer. When one thinks of the farm demand for automobiles, tractors, trucks, petroleum products, tires, farm machinery, electrical equipment, fertilizers, insecticides, and other products, it is apparent the agricultural industry is important not only for the production of food and fiber, but as an outlet for the products of the purely industrial plants of our nation.

Weiss (7) in his report to the Committee on Labor and Public Welfare (2/20/52), entitled "Manpower Chemistry and Agriculture," shows that where one farm worker in 1900 used 2.2 hp, in 1950 he used 33.0 hp. These figures are not directly comparable since much transport power is involved, but they do indicate the rapid shift in power utilization by workers in changing from animal power to mechanical-power equipment. It is this utilization of mechanical equipment that has made it possible to produce an acre of wheat today with 3 man-hours of labor, where a century ago 50 man-hours were required; or produce as much corn per worker in 5 min today as could be produced in 1½ man-hours 80 years ago. Other comparisons could be made, but these are so well-known as to require no further mention.

The Better Farmer Appreciates the Value of Technology

Today the 4.5 million farms are largely staffed with a new type of farmer, a farmer who appreciates the value of technology because technology is essential to him. Since he uses mechanical power to do the tasks formerly done by hand labor, he has become conscious of capital investments and fixed charges. He realizes that a majority of our population is dependent upon farmers for their food and fiber supplies. This motivates his efforts toward volume production of quality crops at as low a cost as possible. He recognizes the necessity for superior management and realizes the dynamic nature of his industry as influenced by a changing technology. Thus our concepts of the farmer of a few decades ago are obsolete even though the competent farmer of today has evolved largely from those of an earlier period. In this evolution, however, there has been much screening for competency due to the competitive nature of modern industrial farm production. The farmer of today is extremely conscious of costs, particularly labor costs, and this has forced him to become machine-



This chart shows labor force trends in the United States

minded, thus contributing to the rapid mechanization of our farms in recent years.

The dynamic effect of farm mechanization and improved land utilization and maintenance upon the economic and social environments of a region is well illustrated in thirteen of our southern states (8) during the decade 1940-1950. These states — Kentucky, Virginia, Oklahoma, Arkansas, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Texas and Florida — faced with the problems of a growing population, rapid industrialization, loss of farm labor, depleted land resources, and the urgent need for farm products, have introduced new farming methods to meet new conditions and requirements.

During this decade population for the region has increased from 37,014,000 to 41,779,000; population in cities of 50,000 or more has increased from 6,502,756 to 8,532,792; farm workers have decreased from 4,711,692 to 3,858,692, while factory workers have increased from 1,458,860 to 2,726,800. Yet in the face of these conditions output per farm worker has been raised 47 per cent by improved practices made possible through farm mechanization. During this decade tractors increased for the area from 254,819 to 841,993, pickup balers from 7,420 to 43,761, grain combines from 57,520 to 134,874, and electrified farms from 562,258 to 1,888,000.

The economic and social impact of this change is illustrated by the following data: Size of farms increased from 123.1 to 142.6 acres; sharecroppers decreased from 541,291 to 356,000; work animals decreased from 5,832,341 to 3,719,600; cotton farms decreased from 1,562,459 to 584,007; cattle increased from 17,935,000 to 26,677,000, and farm bank deposits increased to over eight times what they were 10 years earlier.

This was accomplished, moreover, by decreasing harvested acres by six million, and by changing cotton land to grassland. Small farms of 10 acres or less decreased 17.5 per cent, and farm income increased 150 per cent for the period.

Thus the great agricultural potentialities of the southern states are coming into reality through agricultural mechanization and improved farm practices. This area serves as an outstanding example of the social and economic impact farm mechanization can have upon an agricultural region.

The question may arise as to whether or not society in general is served by mechanization such as has taken place in American agriculture. It must be admitted there are some hazards, as well as advantages. Also circumstances may enhance or depress such developments.

Fruits of Technological Advancement More Generally Enjoyed

In the United States our form of government has promoted individual freedom, initiative, self-reliance, and, in general, personal rewards for human effort. In no other country can be found more freedom for human enterprise. While many imperfections may exist, and improvements should always be sought, the fact remains that more people in this country enjoy the fruits of technological advancement than can be found elsewhere. On top of this, our nation has had the advantages of vast natural resources to stimulate technological progress. These things, when put together, have made it possible for a minority of workers to produce the foods and fiber required to maintain a relatively high standard of living in our nation. Wirt (9) in his address at the 1951 annual meeting of the American Society for Engineering Education stated: "By 1951 one individual on the farm should be able to support 15 or more persons, thanks largely to power farming."

Johnson (10) in a paper presented before the Chicago Section, Society of Automotive Engineers, Feb. 12, 1952, in referring to the benefits of mechanized agriculture stated: "In this country the average American needs to lay down only 26 cents out of every dollar he earns to feed his family. That is in the face of present comparatively high food prices. In the better agricultural countries of Europe the food costs run around 45 per cent (including subsidies). In a country like Italy, it is around 75 per cent. In China and India it takes 90 per cent of the average wage earner's dollar to keep body and soul together for him and his family."

Thus in this country efficiency in farm production through mechanization has developed an abundant food supply at reasonable cost. Here the worker has left out of his wage dollar a high percentage to spend for those other things which contribute to human comfort and security. Mechanization of farming, as in industry, has magnified the importance of the individual as well as his income, thus contributing to an advanced standard of living for the wage earner and his family.

High efficiency in production also is a factor in national security. During the wars of the past 50 years our agriculture through the utilization of mechanical aids has maintained adequate food and fiber production with fewer workers. This has contributed both directly and indirectly to national security programs. The potentials in such contributions have never been fully realized.

One of the basic problems encountered in food and fiber production is the relation of land resources to population needs. Over a period of years, croplands harvested in this country have varied but little. Actually no more cropland acres were harvested in this country in 1951 than in 1932. Production, however, was about 75 per cent greater in 1951. Better techniques, more timely operations, better varieties and species of crops and livestock, together with better management when aided by mechanical equipment and modern chemicals have contributed to better yields. This is likely to continue. Dr. Robert M. Salter (11), chief, U.S. Soil Conservation Service, recently stated: "Several studies aimed at estimating agriculture's maximum production capacity are under way. I have examined preliminary results of some. They indicate that with the best combinations of known practices put into use on all farms, production could be increased from 60 to 70 per cent. The studies indicate, for instance, that average corn and cotton yields in the United States could be increased 75 per cent. The potential for small grain and soybeans doesn't appear to be quite that high, but for hay and pasture it appears that we could double our forage production through grassland improvement."

Expansion of Urban Areas Cuts Cropland Areas

While the potentials in unit production in agriculture are far from full realization, the fact remains that available land areas for farming are relatively limited. Even though new lands may be brought into production through reclamation or other forms of land development, the expansion of urban areas into productive farming sections continues. The expansion of rural electric service and the convenience of family transportation obtainable through the automobile have encouraged city folks to seek "ranch-house living" in the surrounding country. Lateral expansion of cities is more rapid than vertical expansion, because modern mechanization has made country living more attractive and comfortable than is possible in crowded urban centers. Due to these tendencies, it is unlikely that cropland areas can be expected to show much net gain in the future.

Within the present century more than 60 million acres of cropland formerly devoted to the maintenance of work animals have been released for human consumption crops. The mechanization of our farms has made this possible. But this cannot go much further, and our population is growing at an accelerated rate. The director of one of our large agricultural experiment stations (Calif.) recently stated in effect: "In the last 50 years twice as much food is being produced from roughly the same acreage. By 1975 the prevailing diet of 10 years ago will demand 100 million acres of new land, or its equivalent. Unrealized gains of the past are not possible in the future — example, conversion from horses to tractors, released 60 million acres. Improved practices must meet the substantial portion of the need."

With so little promise from acreage expansion our future hopes lie in better yields from the farmland available. The engineer in agriculture, working with the chemist and the agriculturist can do much to meet the food and fiber demands of an expanding population under relatively fixed land areas. Surely there is every reason to anticipate ample supplies of farm products needed to maintain high standards of living for all working people and their families for many generations to come. However, the strength of *(Continued on page 704)*

Determining the Effect of Topography and Design on the Characteristics of Farm Ponds

By R. P. Beasley
MEMBER ASAE

A METHOD will be presented by which the characteristics of farm ponds can be determined prior to construction. It would be an advantage to be able to determine in advance the capacity of the pond, the amount of earth in the dam, the surface area, the area of maximum depth, the depth of water at all points and the distance the earth must be moved in building the dam.

The most efficient pond is one that stores the greatest quantity of water for the least amount of work required in its construction. The most important factors which affect this efficiency are as follows and should be considered in its design:

1. The topography of the area
2. The radius of curvature of the pond dam
3. The depth of water in the pond
4. The depth of water stored above the original ground line compared to the depth obtained by excavation
5. The top width of the dam
6. The side slopes to be used on the dam and in the excavation
7. The amount of freeboard to be provided.

The extent to which these factors affect the efficiency of a pond can be determined by a graphical analysis in which the first step is to plot a contour map of the pond site. Fig. 1 is a contour map of an inverted V-shaped topography of 4 per cent slope.

The particular pond design to be analyzed for this location is next selected. The design values to be used in this example are indicated in Fig. 2. The maximum depth of water in the pond is 8 ft, the depth of water stored above the original ground (designated "fill") is 4 ft, the depth of water obtained by excavation (designated "cut") is 4 ft, the top width of the dam is 8 ft, the side slopes of the dam are 3 to 1 on the water side and 2 to 1 on the backslope, and the freeboard is 3 ft.

The radius of curvature of the pond dam is selected to be 125 ft. Using this radius, the center line of the dam is drawn on a contour map of the site, similar to that in Fig. 1 and the contour lines are renumbered to indicate the height of the dam at various points (Fig. 3). The height of the dam at the deepest point is 8 ft, which is obtained from Fig. 2 and must be considered in locating the centerline of the dam on Fig. 3. At the left end, the center line of the dam is extended tangentially until it intersects the zero height-of-dam contour. At this point the height of fill is zero. The spillway is located at the right end of the dam and the center line is extended until it is at the $2\frac{1}{2}$-ft height, at which point the spillway is dug into the ground $\frac{1}{2}$ ft, giving 3 ft from the top of the dam to the bottom of the spillway as required. The height of the dam at any point along the center line can be determined from the height-of-dam contours.

With the height of dam at the centerline known, the area of section of the dam at any point can be computed. A formula for this, which is sufficiently accurate, is as follows: Area of section $= 8H + 5/2H^2$, where h is the height of dam.

To determine the volume of earth in the dam, it is necessary to divide it into a series of sections, compute the volume of each section separately, and then add the volumes of the

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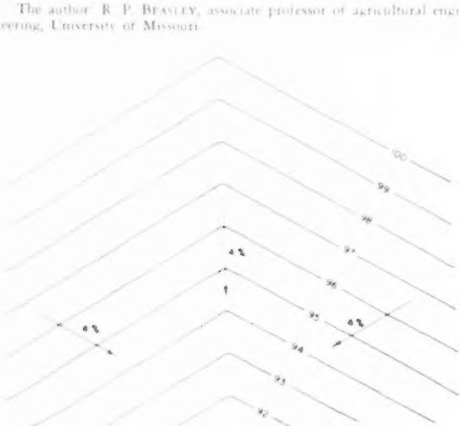

Fig. 1 Topography of the site for the pond

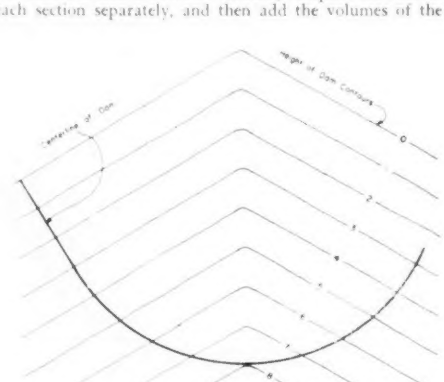

Fig. 3 Contours indicating height of the dam

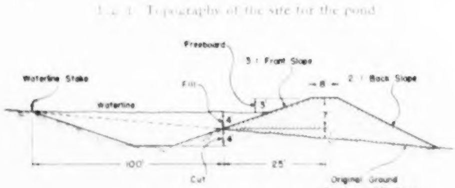

Fig. 2 Cross sectional view of the pond

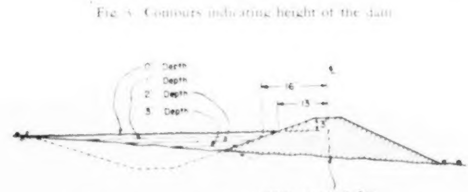

Fig. 4 Water stored above original ground surface

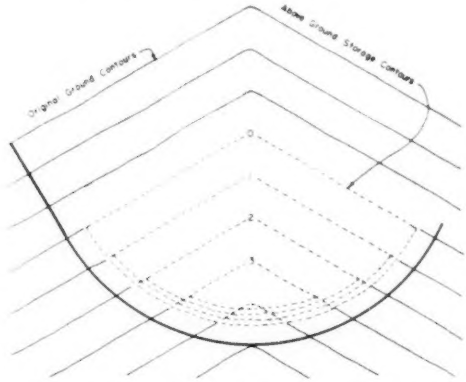

Fig. 5 Extent of water storage above original ground surface

individual sections. It is convenient to divide the dam into sections between the contours indicating dam heights. The total volume of earth in the dam in this example is 1376 cu yd.

The next step is to determine the volume of water in the completed pond. It is noted in Fig. 4 that the volume of water stored above ground, indicated by the shaded portion of the sketch, plus the amount of earth excavated would give the total volume of water in the pond, assuming that there is no excavation back of the water line. The amount of earth excavated will equal the amount of earth in the dam, in this case 1376 cu yd.

The depth of water stored above the original ground would be indicated by the above-ground storage contours in Fig. 5. The area enclosed by each of the above-ground contours is determined. One way to measure these areas is with a planimeter. The volume stored between each of these levels is computed by taking the average of the upper and lower areas and multiplying by the distance between them, 1 ft. The total of these elements of volume is equal to the volume of water stored above the original ground surface. In this example, the amount of water stored above the original ground surface is 731 cu yd and the amount of earth excavated is 1376 cu yd, giving a total water storage capacity of 2107 cu yd.

The actual depth of water in the completed pond can now be determined. This is done by trial and error. Depth of water contours are first drawn in as if the excavation were made on a 3-to-1 slope from the water line. The pond capacity is computed using these trial contours, following the same procedure that was used to determine the volume of water stored above the original ground surface. If this trial pond capacity is less than the actual pond capacity as computed (2107 cu yd), it

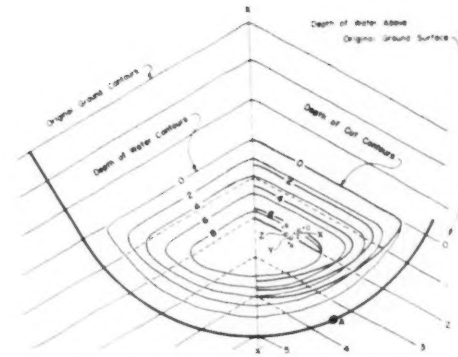

Fig. 7 Contours showing the depth of excavation required and the distance earth must be moved to be placed in the dam

will be necessary to excavate back of the zero-depth contour line to secure enough earth for the dam. (If this is necessary, a different method of solution is used which will be explained later.) If this trial pond capacity is greater than the computed capacity, it indicates that the excavation was made at too steep a slope and more earth was removed than would be required in the pond dam, in which case the trial contours must be adjusted until the trial pond capacity is equal to the pond capacity as computed. These contours then represent the depth of water in the completed pond (Fig. 6).

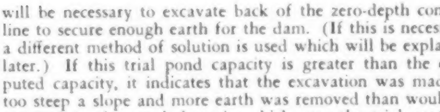

Fig. 8 Cross-sectional view of the pond on a steep slope

To determine the work required to build the dam, it is necessary to compute the distance that the earth is moved. In this method it is assumed that the pond is symmetrical about line $X—X'$, in Fig. 7, and computations will be made for one-half of the pond only. Point A is located so that it will represent the center of volume of the earth in one-half the dam. The total of the volumes of the sections of one-half the dam to the right of point A is equal to the total of the volumes of

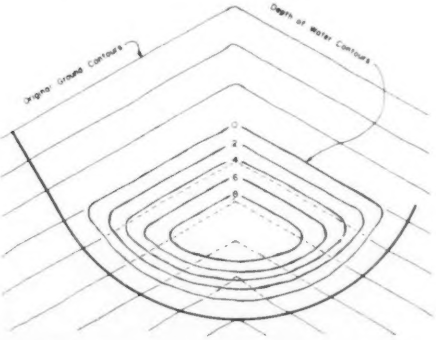

Fig. 6 Contours representing depth of water in the pond

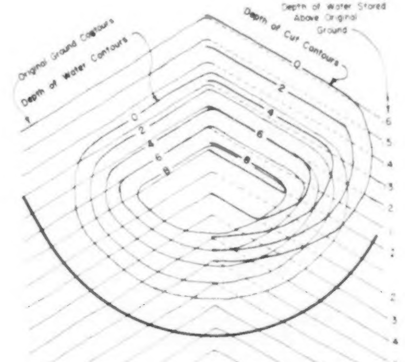

Fig. 9 Contours showing depth of cut and depth of water in the pond when excavation is required back of the waterline

the sections to the left of point *A*. If the pond were not symmetrical, it would be necessary to compute each half separately.

Contour lines are now plotted which will represent the depth of excavation required at various points. If the depth of water above the original ground surface, which is represented by contours (Fig. 7), is subtracted from the depth of water in the pond, the difference will be the depth of cut. Points of equal depth of cut are thus located and lines connecting these points are called depth-of-cut contours. The volume of earth excavated between adjacent levels or depth-of-cut contours can be determined by obtaining the average area enclosed by adjacent depth-of-cut contours and multiplying by the vertical distance between them. The total of all these volumes should equal one-half the total amount of earth excavated or one-half the amount of earth in the pond dam, since only one-half the pond is being considered.

DETERMINING POINT IN CENTER OF AREAS ENCLOSED BY DEPTH-OF-CUT CONTOURS

A point in the center of each of the areas enclosed by the depth-of-cut contours is next determined. The area enclosed by the contour is divided into two halves by drawing a vertical line through the area. To be sure the areas on the two sides of the line are equal, they may be measured with a planimeter. If necessary, the line is moved slightly one way or the other as may be required to make the two areas equal. In a similar manner the area is divided into two equal areas by a horizontal line. The point of intersection of the horizontal and the vertical line is the center of the area. The center points of the various areas are designated as 0, 2, 4 and 6 in Fig. 7. A point midway between 0 and 2 will designate the center of volume of the earth excavated between the 0 and 2-ft depth-of-cut contours. This is point *x* in Fig. 7. Points *y* and *z* indicating the center of volumes between the 2 to 4-ft and 4 to 6-ft depth-of-cut contours are similarly located. Multiply the volume of each of these elements by the distance from its center of volume to the center of volume of one-half the dam (point *A*). The total of these products divided by the volume of earth excavated in this half of the pond will be the average distance that the earth must be moved to be placed in the dam. In the example, this distance is 59 ft. The amount of work required can be determined by multiplying the amount of earth excavated in cubic yards by the distance it is moved in feet.

In determining the pond characteristics when excavation is required back of the water line as indicated in Fig. 8, the procedure is the same as discussed previously up to the step represented by Fig. 6. A pond with a 75-ft radius of curvature, a 5-ft fill and 3-ft cut on an inverted V-shaped topography of 12 per cent slope is used as an example when excavation is required back of the water line. If when the trial water depth contours are drawn, it is found that excavation back of the water line is required, the next step is to draw in trial depth-of-cut contours on a 3-to-1 slope, as indicated in Fig. 9 for one-half the pond, assuming the pond is symmetrical. These depth-of-cut contours are adjusted until the volume of excavation is equal to the amount of earth in one-half the dam. The center of volume of the excavation can now be determined and the average distance the earth must be moved to be placed in the dam can be measured.

The depth of water in the completed pond can be determined at various points by adding the depth of cut to the depth of water stored above the original ground surface. Depth-of-water contours can then be drawn in as indicated in Fig. 9. The water capacity and the surface area of the pond can be determined from these depth-of-water contours.

This method of judging the suitability of various sites for ponds and of determining the most desirable pond design at a particular location may be used on any topography regardless of the steepness or irregularity of the slopes.

A number of different pond designs on various types of topography have been analyzed by this method and comparisons made as to the amount of work required in relation to the water-storage capacity, the capacity in relation to the amount of earth in the dam, and the surface area in relation to the area of maximum depth. These findings are to be published in the Missouri Agricultural Experiment Station Bulletin No. 566.

Cutting Action of a Mower

(Continued from page 697)

6 Cutting over a larger part of the cycle also decreases the magnitude of the average cutting force and thus tends to reduce the unbalance from this source. However, in order to maintain adequate cutting velocities, cutting should not take place near either end of the stroke. Suggested limits are 45 deg from either end for a single reciprocating knife and 30 deg for a double-knife machine. The duration of the cutting period for a given spacing of blades on the knife is determined primarily by the front and rear widths of the cutting elements.

7 The use of two reciprocating knives instead of one tends to minimize unbalanced forces (both inertia and cutting). For a given stroke and speed, the double-knife unit gives twice the cutting velocity at any crank angle and allows twice as great a feed rate.

8 With a guardless, double-knife mower, there is a possibility that some of the stalks may be pushed ahead and not cut because they do not slide off to one side of the front edge of the blade. Controlling factors are the feed rate, the front width of the blades, the coefficient of friction of stalks against the front of the blade, and interference of other stalks.

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Appraisal of Farm Mechanization

(Continued from page 701)

our future lies in more and more reliance upon science and technology. Mechanization must continue. To revert to human and animal power means loss of living standards. If we are unable to provide energy needs from present expendable resources, new forms must be discovered and utilized.

In a democracy such as our own, where people are free to think and act, human initiative always will be available to find solutions to new problems. Our own achievements in the past provide that assurance for continued economic and social gains for our citizens. Mechanized farming offers promise of greater efficiencies in worker output, better yields from the land, less waste, and improved quality. These things contribute to continuing economic and social gains for our people.

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Determining Time and Amount of Irrigation

By D. B. Krimgold
MEMBER ASAE

IN THE July issue of AGRICULTURAL ENGINEERING there appeared a paper by van Bavel and Wilson (1)* which may well prove to be a turning point in irrigation practice particularly in the so-called humid regions. I say this with conviction derived from nearly 20 years of work in the fields of agricultural hydrology and agricultural climatology and from basic training and sustained interest in irrigation. It may be unorthodox, but I cannot think of a more effective way to discuss this important development than to relate my recent experience in planning irrigation on my own farm in central Maryland.

Two years ago after some 18 years of research in agricultural hydrology I acquired a 182-acre farm in Carroll County, Maryland. My plan is to develop on this farm an enterprise capable of producing a decent stable income. A study of the climate, soils, and economics of crop production led me to decide on beef cattle, cow and calf, as the principal enterprise. Of the 182 acres about 14 acres are in woods and 8 acres are in roads, farmstead, or are otherwise unavailable for either pasture or cropping. This leaves 160 acres which must be divided between hayland and pasture. With a crop rotation including four years of hay (alfalfa-brome-ladino) the limiting factor determining the number of animal units is the carrying capacity of the pasture. My own studies and observations, and the experience of others in our area, show rather definitely that in May and June, and again in September and October, our pastures will carry 1½ animal units to the acre, but that it would be imprudent to count on less than one acre per animal unit during July and August. This means that with 80 acres of pasture I can carry only 80 head and must let the pasture be underutilized two-thirds of the time. The alternative is to stock the pasture to its May-June, September-October capacity and resort to either supplemental irrigation or supplemental feeding during July and August. It is not hard to see that supplemental irrigation is the better solution.

The most efficient use of the hayland under our conditions is to keep it in a mixture of alfalfa, ladino, and perennial grasses as long as possible. This means a rotation with four years of hay, one year of row crop, and one year of small grain. In our area the best-paying row crop is a medicinal plant which, with ample moisture and fertilizer and with good cultural practices, could net up to $400 per acre. But this crop can seldom be planted before the middle or end of June and must go through the rain deficient months of July and August during its most critical period with the result that the great potentialities of this crop are fully realized only during the rare years when the crop can be planted early or when the amount and distribution of rainfall and the temperatures in July and August are usually favorable. Here again the answer is supplemental irrigation. It is understandable why some people in our area, like many in other areas for other but equally valid reasons, are thinking more and more in terms of supplemental irrigation.

There are a number of aspects that must be carefully considered in connection with irrigation. There are the chemical and physical properties of the soil, the depth to the water table, the slope and configuration of the land, the source and dependability of the water supply, power, and also some legal aspects. These are all connected with the initial surveys and construction or installation phases. With my own background and the assistance from our state agricultural extension service and other agencies I anticipate no particular difficulty in solving these problems. The more difficult and perplexing problem, that of scheduling of irrigation, comes after the installation is completed.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

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*Numbers in parentheses refer to the appended references.

The keys to successful irrigation particularly in humid regions are the proper time of application of irrigation water, the correct quantities per application, and, in the case of sprinkler irrigation of tilled land, the correct rate of application and drop size.

For a given crop and soil it is possible to determine the depth of unimpeded root penetration, the depth to the impeding stratum, or the depth to the water table. With this informaion and the "available water" (field capacity minus wilting coefficient) in the root zone it is not difficult to determine the maximum amount of water per application. Water much in excess of field capacity occupies space which for maximum crop production should be occupied by air. In coarse-textured and in well-aggregated, fine-textured soils such water remains in the soil for only a short period (12 to 24 hr). In poorly aggregated, fine-textured soils water in excess of field capacity will remain much longer and will do more harm than good. The low infiltration capacity of such poorly aggregated, fine-textured soils make them unsuitable for sprinkler irrigation — the only feasible method of irrigation on steeply sloping, irregular land. For our case and for practical purposes elsewhere the maximum quantity per application can therefore not exceed the "available water" in the root zone. There appears to be some evidence (11) that in the presence of ample plant food, maximum production would be obtained if the moisture content of the root zone could be kept at or near field capacity at all times during the growing season. But to do so would require practically continuous irrigation. This may be possible with a permanent sprinkler system, the initial cost of which would be prohibitive except in very special cases. On irrigated pastures it may be preferable to keep the moisture content somewhat below field capacity to prevent damage to the plants and the structure of the soil by trampling of wet soil.

These are all interesting but largely academic considerations. In practice it is the water supply — the capacities of the pump, pipe lines, and sprinklers, and the most efficient use of the operator's labor — that determines the quantity of water per irrigation. For most efficient irrigation consistent with these practical limitations, the time to apply irrigation is when the amount of moisture in the soil has been reduced from the optimum by an amount equal to that which can be applied most efficiently with a given setup.

This simple and common sense approach to the determination of time of irrigation, the concept of *potential evapotranspiration*, the formula for computing evapotranspiration and the bookkeeping procedure used in determining the net amount of soil moisture used up in a given period are the quintessence of the Thornthwaite method.

In their paper, entitled "Evapotranspiration Estimates as Criteria for Determining Time of Irrigation," van Bavel and Wilson attempted with partial success to demonstrate how Thornthwaite's formula and bookkeeping procedure can be used in estimating moisture content in the soil. Their failure to grasp Thornthwaite's common-sense approach to the determination of time of irrigation led them to say that "... in order to use the evapotranspiration approach, the rooting depth of the crop, the moisture characteristics of the soil, the moisture-tension tolerance of the crop, evapotranspiration rates and a record of rainfall will have to be known." They have as a matter of fact made the problem far more complicated than it needs to be and made Thornthwaite's method appear far less workable than it really is. What, for instance, do I care about moisture characteristics of the soil and some of the other items listed by van Bavel and Wilson? If with my setup one inch is the most efficient and economical quantity per irrigation, then what difference does it make what the total "available moisture" is or what the "moisture-tension tolerance" of the crop is. (I suppose they mean the good old "wilting coefficient".) For maximum crop production obtainable with my setup, I need only to know when a net of one

inch of the soil moisture has been used up, which is the time to turn on the pump. Only if the total "available moisture" in the root zone were less than one inch would I be concerned with the moisture characteristics of the soil. But on such a soil irrigation would hardly be economically feasible.

Van Bavel and Wilson summed up the situation with regard to the present methods of determining the time of irrigation very well in the following statement:

". . . As a result, there are now available tensiometers to measure the soil-moisture tension directly, and gravimetric plugs, Bouyoucos gypsum blocks, nylon blocks, Colman fiberglass blocks, thermal conductivity units, and other types of instruments which measure, indirectly, the soil-moisture content from which the soil-moisture tension can be derived.

"Even when used in research work, these methods are expensive in purchase cost and in time required for operation and interpretation. For practical use by the farmer, they are all but out of the question. Moreover, there has been no single method developed which is satisfactory for field use. This is due mainly to the small soil volume which is measured by any of these methods and the resultant variation between replicate installations."

I would like to indorse this statement strongly and to underscore the last sentence by saying that the difficulty lies not in developing a satisfactory "soil moisture meter," which is yet to be accomplished, but that because of the great variability in soils it is highly improbable that even a poor approximation of soil moisture can be gotten with a reasonable number of field installations. The value of van Bavel and Wilson's paper is that it calls attention to Thornthwaite's method of scheduling irrigation.

Development and Application of the Thornthwaite Method

I had the privilege of rather close association with Dr. Thornthwaite when we were both in the research division of the Soil Conservation Service, USDA, in Washington. I watched with great interest the development of the method and its many applications. Thornthwaite first presented the application of his method in scheduling irrigation in 1944 before a meeting of the North Atlantic Section of the American Society of Agricultural Engineers. Unfortunately this truly remarkable paper was not published. In this and in subsequent papers, some of which are listed in the appended references, Thornthwaite and others have demonstrated how well his method works in estimating soil moisture. Van Bavel and Wilson's Table 2 (AGRICULTURAL ENGINEERING, July, 1952, page 420) could be considered another illustration if we could assume that the soil of the small experimental plot at Raleigh was sufficiently uniform and the tensiometer installations sufficiently numerous to make it possible to arrive at the "actual" dates of irrigation with tensiometer determinations of soil moisture. No one who takes the trouble to examine the evidence presented so far by Thornthwaite and others can deny that the method works. It works well enough so that Seabrook Farms in New Jersey, one of the largest vegetable farms in the world, accepted it as the basis for many of its farm operations including the scheduling of irrigation. I decided to use Thornthwaite's method in scheduling irrigation on my own farm and expect it to work better than any other method now available.

Van Bavel and Wilson have done a real service by demonstrating the validity of Thornthwaite's method in estimating soil moisture; however, like others before them, they did not fully grasp the significance of Thornthwaite's approach and have taken liberties which may not be fully justified. They state that "according to Thornthwaite the daily evapotranspiration for the Raleigh area is 0.21 in in July." I do not think that the method is so crude as to require such an unreasonable assumption. On checking I find that this was an unwarranted simplification and that values of evapotranspiration can and should be determined for individual days.

I fully agree and strongly indorse van Bavel and Wilson's statement that "for purposes of rationalization of irrigation practices the possibilities of estimating soil moisture content through evapotranspiration and measurement of rainfall should be evident." I would go further and say that there is sufficient evidence to justify the use of the method in irrigation practice at the present time but would like to caution against misinterpretations and against attempting to apply the method on private land without consulting its originator.

Thornthwaite has gone beyond the theoretical formula stage. He embodied the results of his investigations in a very practical device for computing the time of irrigation. With this device, which operates much like a circular slide rule, and the accompanying instruction, anyone able to read a scale can easily determine the time it will take for a given amount of moisture to be withdrawn from the soil. The only additional information required is a current record of rainfall which should and can be readily obtained by the farmer with an inexpensive commercially available raingage. This device which Thornthwaite calls an "irrigation guide" is soon to be made available commercially. I understand that Thornthwaite's method is being subjected to various tests by workers all over the world and that he and others are constantly at work on refinements and improvements of the formula and the method. It is intended that as it becomes available the new information will be furnished to users of the "irrigation guides".

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(Continued on page 707)

Progress in Farm Building Mechanization

By Deane G. Carter
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PROGRESS in coordinated research has been an outstanding achievement of agricultural engineering in the past decade. This is well illustrated by the studies of farmstead mechanization; in the use of power in place of man labor, and in the planning of buildings to save time, travel, and energy.

Automatic handling and processing of farm feeds is but one of the many farmstead problems in the over-all objective of applying engineering methods to improve farming operations. Gains have also been made in crop processing, drying, conditioning, and storage. Engineering research in dairy housing and operations and meat-animal production has much to contribute to efficiency and economy.

Time-and-travel studies in beef-cattle feeding, for example, reveal an extremely wide range in the practices within one community and with comparable numbers of animals; at the extremes for preparing feed, one operator walked 6,346 ft to get a ton of feed ground and ready to take to his cattle, while another got the same work done with 109 ft of travel. In feed distribution, a high mark of 11,300 ft of travel for each ton was recorded to get ground feed from bin to bunk, contrasted with 273 ft in the most effective plan studied. Man time varied from a high of 47 min to a low of 15 min to the ton for preparation, and from 37 min down to 10 min for distribution of feed to the animals.

Other records have been obtained that show a wide difference between high and low work requirements for hog and poultry feeding and for dairying. Wallace Ashby has calculated the farm labor load in and around the buildings at something over seven billion hours a year. On a great many midwest farms, the dairy and livestock programs build up this labor load to two-thirds or more of the total labor requirements for the farm.

Automatic feed handling, grinding, and conveying is a big step in the direction of labor efficiency. Beyond this the buildings must be designed for installation and use of the equipment. The grouping of the buildings in the farmstead affects the amount of time and travel and the type of equipment that can be used.

Building space must be planned with a view to flow lines and distances, as well as to economy and suitable installations of equipment. In a broad sense, farm buildings must be vitalized with electric service, mechanisms, and functional design if they are to serve today's needs. The following conclusions stand out in any summary of this problem of mechanization:

1 No matter how good an individual structure, unit, or device may be, it becomes significant to the farmer only as it is made a part of the operating program for the farm.

2 No one specialist or group can dominate building mechanization. We must have the coordinated effort of men in structures, electrification, machinery and production; public service research and extension services as well as industry are also concerned; and they must work together from the time the research is started until the results are acceptable to the farmer.

3 Far more effective work can be done by means of cooperative research with enough funds and men to permit continuous and intensive work than is possible with fragmentary, individual, or part-time projects.

4 The farmer's problem goes beyond feed grinding and handling, for he must gather and store his feed supply, condition it against loss or spoilage, process and distribute feed to his animals, and clear away the manure. We shall not be through with research until the entire sequence of operations is powered, mechanized, and made as nearly automatic as it is practical to do.

Recommendations can be briefed into five items:

1 Expand on a research program to solve the remaining problems of mechanizing farm production.

2 Depend on research to develop each needed machine, part, or entire assembly so that manufacturers can produce them in quantity.

3 Support the redesign of farm structures, both on-site and manufactured, together with research in time, motion, energy, and arrangement, so as to get the most effective setting for mechanization.

4 Insist on inter-relation between industry and public service in research, manufacture, sales, and application so that the talents and experiences of both can be utilized.

5 Consider the possibilities for a cooperative regional research program under the terms of the Research and Marketing Act as a means for better coordination and additional support, and to make use of the capacities of people without regard to their affiliations.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1951, as a contribution of the Rural Electric Division.

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Performance of Castor Bean Hulling Plants

By L. G. Schoenleber and W. M. Hurst
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IMPORTS of castor beans for milling purposes ranged from 196 to 390 million pounds annually for 1937 to 1948 inclusive, with an average of 287 million pounds per year for the 10-year period.

Efforts are being made to grow the crop in the United States on a large scale to insure an adequate supply of castor oil for the military and civilian needs of this country. Contracts were made through the PMA castor bean production and procurement program for the planting of 84,000 acres in 1951, largely in Oklahoma, Texas, and California. The program for 1952 contemplates the planting of 200,000 acres.

The crop in foreign countries is produced and harvested mainly by hand methods. Mechanization in production, harvesting, and processing will be necessary for economical production in this country.

The purpose of the hulling plants is to remove and separate the hulls and trash from the beans without injury to the seed. This is an important operation. Beans which are cracked and broken lose oil and gradually become rancid. Trash, hulls, and broken or cracked beans lower the quality of castor oil produced.

Location and Description of Hulling Plants. During the 1951 season PMA operated plants or leased equipment for hulling castor beans at five locations in Oklahoma and Texas. In addition, portable hulling equipment was used at one location in Texas. All of these plants were operated for the first time on the 1951 crop. The equipment was new, but the buildings were in most cases originally intended for some other purpose or were rebuilt for hulling-plant use. The plants are normally centrally located in the castor-bean-growing area on a railroad siding in a town.

Plants owned and operated by a commercial firm were in six locations of Oklahoma and Texas. Four of the six plants began operations in 1951 and two had been used prior to that time. Field hulling with portable machines is the general practice in California and the beans are handled by grain elevators at country points prior to shipping to oil mills.

The PMA and commercial plants used the same type of equipment and were based largely on experience gained by a commercial firm prior to 1951.

There are two general types of hulling plants in Oklahoma and Texas: (1) quonset-type buildings for housing the hulling machinery and the storage of hulled beans, with an outside elevated bin for hulls, and (2) structures, either wood or metal, of sufficient size to shelter the hulling machinery, with outside metal bins for storage of hulled beans. Table 1 shows in general the type of buildings and equipment in the Oklahoma and Texas plants.

The majority of the installations with two hullers were designed for capacities which ranged from 2000 to 6000 lbs hulled beans per hour and are intended for hulling about 5000 acres of beans per hulling season with the larger units.

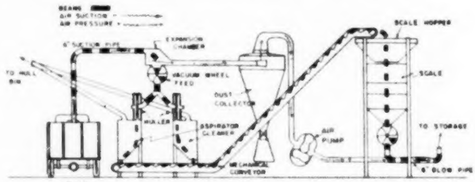

Fig. 1 Diagram of castor-bean-hulling equipment

Hulling-plant equipment consists essentially of one or two hulling units and blowers, weigh scales with bin-conveying equipment, and electric motor drive. The huller contains disks which are either 24 or 36 in in diameter, rubber-faced with a portion cut out near the center. These disks operate with the axis of rotation in a horizontal position with one disk mounted rigidly. The blowers are used to blow the loose hulls and trash from the beans into a bin. The weighing scales are either of the automatic-weighing or manual-operated type. Pneumatic-conveying equipment is used almost entirely for moving the unhulled beans received at the plant to the hullers and for conveying the hulled beans from the weigh scales to storage or freight cars. Cup or canvas-bottom conveyors are generally used to move beans from the huller to the weighing bin. Electric motors used to drive the equipment in the hulling plant ranged from fractional to 15 hp with a total rated capacity of 40 to 50 hp. Of this equipment the two hulling units required from 20 to 25 hp, the pneumatic conveying system usually 15 hp, and the cup or canvas conveyors only fractional horsepower electric motors.

Present Methods of Operation. The plants are designed to receive unhulled beans from the farm. The unhulled beans are brought to the hulling center in vehicles of various types and sizes. Few have endgates or provision for dumping.

Fig. 1 shows the diagram of a castor bean hulling plant.

The unhulled beans are moved by a pneumatic system from the farmer's load to the huller. They are then separated from the air stream by means of a vacuum unloading wheel. The beans then pass through hullers and drop through an aspirating chamber where the hulls and light trash are pulled off and blown into an outside bin for disposal. The hulls are either hauled back to the farm or disposed of by other ways. The hulled beans drop onto a conveyor, normally of the continuous-cup type, and are elevated to a weight

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TABLE 1. TYPES OF STRUCTURES, EQUIPMENT USED AND RATED CAPACITY OF CASTOR-BEAN HULLING CENTERS

Plant No.	Structures: Plant: Type	Structures: Plant: Floor dimensions, ft	Structures: Storage(a): Type	Hullers: No.	Hullers: Size diameter, in.	Types of elevators and conveyors: Receiving	Types of elevators and conveyors: To scales	Types of elevators and conveyors: To storage	Rated capacity hulled beans, lb/hr
1	Quonset	[illegible]	Quonset	[illegible]	[illegible]	Drag	Cup(d)	Pneumatic	6,000
2	Quonset	[illegible]	Quonset	[illegible]	[illegible]	Pneumatic	Cup	Pneumatic	6,000
3	Warehouse	(b)	Warehouse	[illegible]	[illegible]	Pneumatic	Cup	Pneumatic	6,000
4	Quonset	[illegible]	Quonset and Bins	[illegible]	[illegible]	Pneumatic	Cup	Pneumatic	6,000
5	Frame	[illegible]	Bins	[illegible]	[illegible]	Pneumatic	Cup	Pneumatic	6,000
6	Quonset	[illegible]	Bins	[illegible]	[illegible]	Pneumatic	Cup	Pneumatic	6,000
7	Frame	[illegible]	Bins	2	[illegible]	Pneumatic	Canvas(e)	Pneumatic	3,000
8	Frame	[illegible]	Bins	[illegible]	[illegible]	Pneumatic	Cup	Pneumatic	6,000
9	Frame	(c)	Bins	[illegible]	[illegible]	Pneumatic	Cup	Pneumatic	6,000
10	Frame	[illegible]	Bins	1	[illegible]	Pneumatic	Canvas(e)	Pneumatic	3,000
11	Frame	[illegible]	Bins	2	24	Pneumatic	Canvas(e)	Pneumatic	2,000

(a) Hulled beans piled on floor of quonset or stored in flat bottom farm type steel bins.
(b) Machinery set up in large cotton-seed storage warehouses.
(c) Machinery in driveway of old grain elevator.
(d) Cups attach to chain - horizontal and vertical upward movement of beans.
(e) Chain-driven canvas trough with sheet-metal half circle flights.

bin and the weight recorded. The beans are then fed by gravity from the weight bin into the same pneumatic system as used for unloading or by gravity to the intake of a separate pneumatic loader and blown into storage.

A composite sample of beans is taken from the hullers during the hulling operations for each farmer's load. The sample is reduced by dividing to 300 g for analysis for moisture, cracked and broken beans, foreign material and unhulled beans and is used as a basis for dockage calculation and payment of beans to the farmer.

The operation of the plant requires one person of the crew for operating the suction unloading on the load of beans. A second is required to operate the machinery, and a third to analyze the samples. In addition, there is a plant manager who usually assists in the plant on jobs where needed besides performing his regular duties. Some plants late in the season when only few beans are received operate on a skeleton crew of one or two men. In such cases the truck driver is relied upon to unload the beans.

Test Results and Observations of Hullers. Cracked and broken beans and foreign material including hulls are considered objectionable in the production of castor oil. Foreign material and hulls contain no oil but absorb oil during the milling process, and thereby reduce the oil yield and impart an objectionable dark color to the oil. Cracked and broken beans lose oil, collect dust, and in time become rancid. For these reasons, the amount of cracked and broken beans, the foreign material, amount of unhulled beans and the moisture content were used as a basis of efficiency of the hulling operations. Table 2 shows the analysis of samples obtained during normal hulling operations and indicates in a general way the quality of the beans for the various operations for the 1951 crop.

The hullers were designed to hull mature dry beans. The majority of the crops in Oklahoma and Texas during 1951 was picked by hand when the beans were dry — below 6 per cent moisture. It is possible that when mechanical harvesters are more widely used moisture will be more of a problem. The hulls are highly hygroscopic. Light precipitation, dense or high humidity will cause the hulls to absorb large amounts of moisture. Attempting to hull the beans when damp will result in a low hulling rate with a high rate of cracked, broken, and unhulled beans.

Since the hulling plants were not designed to recirculate the unhulled beans for rehulling, adjustments of the machines were made to obtain a balance between number of cracked and broken and unhulled beans. If the operator finds too many unhulled beans he will adjust the disks with less clearance. This will hull more beans but the number of cracked and broken beans will be larger. An analysis of samples taken from storage showed 4 to 6 per cent of the beans in storage were unhulled. On a 75 per cent hulling-yield basis (which is considered a high hulling yield) the per cent foreign material due to unhulled beans amounted to 1 to 1.5 per cent. The yield probably would be more nearly 60 per cent indicating a foreign material content of 1.6 to 2.4 per cent due to hulls on unhulled beans. Foreign material from hulls on good beans plus the free foreign material content of 2 to 3 per cent would total perhaps 3.6 to 5.4 per cent.

The pneumatic system for all practical purposes was found to damage a negligible number of beans in conveying the unhulled beans from the farmer's load to the huller, except when the beans were carried to the huller too fast and backed up into the pneumatic rotary unloader. In such cases a few would be hulled and broken.

Cracked and broken beans resulting from hulling varied widely in different loads and to some extent in different samples from the same load. In one test cracked and broken beans from 16 samples obtained from the same load after hulling ranged from 1.9 to 8.9 per cent with an average of 4.5 per cent. In general, the 36-in disk hulling machines damaged an average of about 5 per cent of the beans.

No measurable damage occurred to the beans in conveying in a continuous-cup conveyor from hullers to scales and in weighing.

TABLE 2. MOISTURE CONTENT, CRACKED AND BROKEN, AND UNHULLED CASTOR BEANS OF SAMPLES TAKEN AT HULLING PLANTS IN OKLAHOMA, TEXAS, AND CALIFORNIA

Location of plant	Beans				
	From huller			From bin	
	Moisture	Cracked and Broken	Unhulled	Cracked and Broken	Unhulled
	Per cent	Per cent	Per cent	Per cent	Per cent
Oklahoma(a)	6.7	5.7	5.7	14.2	5.1
" (b)	...	...	...	11.3	6.1
" (b)	...	...	...	11.0	[illegible]
Texas(a)	5.7	4.5	[illegible]	[illegible]	[illegible]
" (a)	[illegible]	4.6	7.4	[illegible]	[illegible]
" (b)	...	...	...	12.5	4.7
" (b)	...	...	...	[illegible]	[illegible]
California(c)	[illegible]	7.[illegible]	[illegible]	...	...

(a) Same lot of beans sampled during hulling operation.

(b) Samples from storage.

(c) Average of samples from [illegible] loads as received at elevators from portable field hullers. Information furnished by California State Department of Agriculture graders.

Some damage occurred in getting the beans back into the pneumatic system beneath the scales with a rotary feeder and in blowing them through 30 to 100 ft of 6-in metal pipe to storage. In one test samples of the same lot of beans which showed 4.6 per cent cracked and broken from the huller, and 9.4 per cent cracked and broken as discharged from the pipe at storage after passing through 100 ft of 6-in metal pipe that had one 90-deg turn. This test on beans from one load showed 4.6 per cent cracked and broken from the huller, 1.5 per cent by the rotary feeder beneath the scales, and 3.3 per cent by the pipe.

In another test, about one bushel of cleaned beans that contained 1.5 per cent cracked and broken and no unhulled beans when passed through the rotary feeder beneath the scales broke 1.8 per cent. Some of the same beans passing through the rotary feeder beneath the scales and blown into storage through 50 ft of 6-in metal pipe with two 90-deg turns showed the piping system cracked and broke 10.8 per cent of the beans. The high damage in the piping systems in the second test was perhaps due to two rather short-radius 90-deg turns for which flexible metal pipe was used. While the length of pipe was over twice as great in the first test than in the second, only one slow-turn elbow of flexible pipe was used.

At one plant where beans were moved through about 30 ft of pipe with one flexible section allowing the end of the line to be pointed upward at about 35 deg, the rotary feeder and line damage was less than the previous examples. While no samples were taken from beneath the feeder, the combined feeder and pipe damage was only 4.0 per cent. Straight runs of smooth interior pipe probably would damage few beans. Some damage might occur due to impact of the beans against the floor or side walls of bins or against beans in storage. The beans have a velocity of perhaps 1,500 to 2,000 fpm when discharged at the end of the pipe.

Attempts were made at one plant to reduce line damage by reducing air velocity. Pitot-tube readings showed an air velocity of 5,500 fpm with no beans in the line. Beans caught in a net at the end of the line of normal operations on one load showed 9.0 per cent cracked and broken beans. Samples from a small lot of beans from the same load moved through the pipe with an air velocity of 4,400 fpm showed 7.4 per cent cracked and broken or a decrease of 1.6 per cent. When the air velocity was increased to the original 5,500 fpm, the percentage of cracked and broken beans in the sample increased to 10.0 per cent which was one per cent higher than the original sample. While the test indicated that air velocity may influence damage to the beans, there is not much margin to work on. The pipe later clogged at an air velocity of 4,400 fpm.

Tests showed no significant differences in germination between beans from the load and from the storage bin following hulling operations when using beans not visibly cracked or broken. Rough treatment of blowing the beans to storage apparently had no immediate detrimental effect on germination. Table 2 shows the amount of unhulled beans from the

huller to be about 6 per cent. Unhulled beans that passed through the machine during the first hulling operations were found could be hulled to about 90 per cent, even though no change of adjustment was made to the machine. This shows the use of equipment to recirculate the unhulled beans would be a desirable feature. The machine could be adjusted for a minimum number of cracked and broken beans and the unhulled beans would be recirculated for hulling.

Particular precaution should be exercised to keep the castor-bean dust in the hulling plant to an absolute minimum. Some people are allergic to the dust and most people around the plants are found to have the discomfort of an irritable respiratory tract. A cleaner kept tight of leaks for the hulled beans in the line and used in connection with mechanical conveyors should help considerably.

Grass, large stems, weeds, seed such as cocklebur, and other foreign material which will not pass between the hulling disks slow up and tend to clog the huller. All such material should be removed before hulling either in field harvesting or with cleaning equipment at the hulling plant. A scalper cleaner located between the rotary feeder and the huller equipped with brushes for keeping the screens clean may be needed. It is doubtful if screening would remove green, immature capsules, but an air cleaner might be used. Occasionally tramp iron such as a bolt or nut damages the rubber facing of the disks indicating the need for a magnet in the feed line.

New Hulling Plant Design. We propose the following changes should be made on the hulling plants in order to obtain a high hulling efficiency and performance. The schematic drawing of the proposed castor bean hulling plant is shown in Fig. 2. In this plan the hulling and cleaning machinery is arranged in two vertical lines. The building is 30 by 32 ft and 28 ft high at roof ridge. The roof is constructed on a 30-deg slope. The building provides a room for an office and seed grading, a space for workshop, two lines of machinery, and elevator and space for related equipment such as dust collectors, machine parts, and storage space. The two vertical lines of machinery consist of (*a*) vacuum feed box, (*b*) scalping screen, (*c*) surge bin, (*d*) hullers, (*e*) cleaner, (*f*) weighing gin, and (*g*) platform scales. The approximate floor space provided for the hulling equipment and office are 8 x 8 ft for each line of machinery; 5 x 4 ft for each elevator; 8 x 16 ft for the office and grading room. The vertical distances required for the hulling equipment as shown on the diagram are 17 and 21½ ft for the lines of machinery and 27 ft for the elevator which is inside the building.

A chain-type, continuous bucket with positive discharge should be used for vertical conveying of the beans to keep mechanical injury to a minimum. Approximately a 25-ft lift is required for conveying the beans from the bottom of the machines in line one to the top of the machines in line two. Return equipment of unhulled beans, not indicated on the drawing, should be provided from the cleaner to the huller.

Approximately a 50-ft lift is required for conveying the hulled beans from the hulling equipment to the storage bins.

All horizontal conveying of beans can be done satisfactorily with a belt-type conveyor. Conveyors should be provided from the hopper-bottom storage bins to the inlet boot of the outside bucket elevator for loading box cars or shifting from one bin to another.

When more than two storage bins are desired the bucket elevator for filling storage bins should be constructed between the bins as shown in Fig. 2. This will provide sufficient slope of the spout from the elevator to the top of the storage bins for satisfactory movement of beans.

Each storage bin should be constructed with a hopper bottom for unloading and should be of sufficient capacity to hold beans to fill one large box car. The bins shown in the drawing are 14 ft 2 in in diameter and 32 ft high.

The hulling plant should be located at a railroad siding with the track extending alongside the storage bins and building as shown in Fig. 2. Space should be provided for the unloading wagons and bins for hulls on the side of the building either opposite the railroad tracks or storage bins.

Another arrangement of the (Continued on page 712)

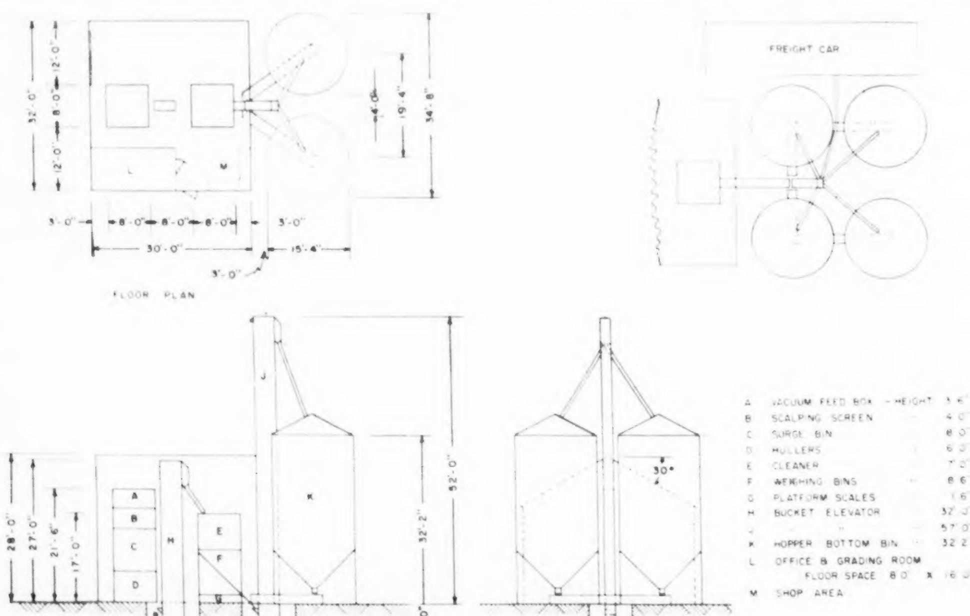

Fig. 2 Schematic drawing of proposed castor bean hulling plant

Production and Uses of Castor Beans

By Donald L. Van Horn

CASTOR beans are the seeds of the castor bean plant, sometimes known as the mole bean or castor plant. The plant is a member of the Euphorbiaceæ or spurge family with scientific name *Ricinus communis*. It is not a legume as the name suggests and has no soil conserving or soil improving properties.

The castor bean plant grows wild in most of the tropical and subtropical areas of the world and under such conditions behaves as a perennial. Under these conditions it may grow to heights of 30 ft or more and behave as a short-lived tree. As grown for commercial production in the United States, the plant is an indeterminate annual, 3 to 10 ft in height, with from one to twenty or thirty spikes or racemes on which the seed are borne in three parted capsules. Castor beans are known to most people in the United States as an ornamental or as a plant to be grown for shade in chicken yards and around farm buildings. The plant is grown commercially for its seeds which contain about 50 per cent oil.

The medicinal use of castor oil which is always uppermost in the mind of persons not familiar with the crop is relatively minor. The oil is actually used mainly as the raw material in the manufacture of many materials needed for civilian and military uses, including many products in everyday use. Important military uses are for the lubrication of jet airplane engines, all-purpose greases, hydraulic and gun recoil fluids, low-temperature waterproof coatings and plastic coatings for electrical equipment. It is also used as a plasticizer in the manufacture of fabrics and explosives. Other uses are in the manufacture of artificial leather, soap, cosmetics, printing ink and special low-temperature lubricants and flexible coatings. The largest single consumer is the protective-coating industry in which, after dehydration, castor oil is used as a quick-drying base for paints, lacquers and varnishes. Many non-yellowing enamels are based on dehydrated castor oil. Castor oil is the chief raw material for the production of sebacic acid which is the basic ingredient in the synthesis of nylon plastic. This nylon-type plastic is used for brush bristles and for jacketing of field wire used by the military.

An older use of sebacic acid is as an intermediate in the preparation of monomeric esters which are useful as plasticizers. It is important in the production of other plastic products because it makes the material moldable at lower temperatures and later keeps them from becoming hard or brittle. Sebacic acid poly-esters are valuable in steam-sealing and in caulking compounds used to prevent leaks in aircraft gasoline tanks because of their high gasoline resistance.

The crushed cake remaining after the oil is pressed from the seed is known as castor pomace. While high in protein, it is not usable for livestock feed because the poisonous constituent in the castor bean, called ricin, remains in the pomace during the crushing process. Although it is possible to detoxify the pomace, the cost of bio-assaying each batch to be sure it is non-toxic prevents use of the process at present. All of the castor pomace resulting from crushing operations in the United States is used as an organic fertilizer.

Castor beans, if eaten, are poisonous to people and to livestock. Care should be taken that children do not eat the attractive seeds and that seeds are not mixed with human food or grain fed to livestock. Because of the poisonous property of castor beans, the seed should not be stored with livestock or human food, or processed with the same machinery, or on the same premises with other oils for food. Anyone offering such contaminated products for sale is subject to the penalties of the Federal Food, Drug and Cosmetic Act and to certain regulatory acts enforced in most states. The pomace is also allergenic and has been shown to be the cause of cases of asthma in persons exposed to breathing the dust from solvent extracted castor pomace.

From 1870 to about 1910, castor beans were grown commercially in several of the midwestern states, particularly in southeastern Kansas. The maximum annual production in this area before the beginning of this century was about 35 million pounds of beans. Production had virtually ceased by 1910, probably due to continued low returns to the grower. This seems to have been due to low price rather than to extremely low yields. The decline in production in the midwest was accompanied by a shift in the location of castor oil mills from the central states to the Atlantic seaboard. With this shift came the use of imported beans.

During World War I, the Bureau of Aircraft Production of the War Department undertook a domestic castor bean production program to procure adequate supplies of castor oil for airplane engines. This production attempt got started late and interest in the project ceased with the end of the war. In spite of lack of information and lack of adapted seed, some 1½ million pounds of beans were produced in 1918.

During World War II, another attempt was made to promote castor bean production in the United States. Some three million pounds of seed were produced in 1943, after which production was discontinued. However, during this period of interest, adapted strains were selected and considerable information was obtained on areas of adaptation, soil and fertility requirements and production methods.

Interest in domestic production of castor beans was resumed in 1947 when a commercial castor bean crushing company set up its own agronomic division to attempt to develop castor bean production in the United States on a sound peacetime basis. The Department of Agriculture has worked with this company and with any other interested party in attempting to establish economic production in the United States. By 1950 this effort had led to a planting of about 7,000 acres mainly for the increasing of improved varieties of seed. This supply of seed of adapted varieties was used to plant some 75,000 acres of castor beans in 1951. About 100,000 acres are being grown in the southern great plains and in the irrigated valleys of California and Arizona in 1952.

Annual requirements of castor oil in the United States consume about 250 to 300 million pounds of beans. In the last two years, imports of castor beans have declined with the corresponding increase in the importation of oil from Brazil. In view of the desirability of having a domestic source of this strategically important material, the federal government is promoting castor bean production through the Production and Marketing Administration. This program is being carried on by furnishing a support price of ten cents per pound for castor beans grown under contract with the PMA or with companies acting under contract with the PMA. Aid is also given in making harvesting and hulling equipment available through this program. Another important feature of the government's program to get castor beans produced in this country lies in the distribution of adapted planting seed to areas which research has shown have a good chance of producing castor beans economically.

Castor beans are being produced this year in Oklahoma and Texas with a little registered and certified seed production in the Arkansas River valley in Arkansas. This production is mainly dry land but some irrigated production is being done on the High Plains of Texas. In 1951 there were about 25,000 acres of castor beans produced under irrigation in the valleys of California and Arizona. This production has been greatly curtailed in 1952 due to losses of the seed before harvest caused partly by loss of capsules from the plants during severe wind storms and partly due to difficulties with harvesting equipment. The problem with volunteer castor beans on vegetable land following last year's severe loss of seed from the

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plants has been a big factor in reducing this acreage. Varieties which have shown very much less shattering, in fact, no shattering under the same conditions where losses occurred last year, are now being increased and it is hoped that these varieties will revive interest in the irrigated valleys in the Southwest.

This crop seems to fit best in the marginal area between corn and cotton, that is, south of the area where corn is the most prominent crop and in the northern part of the cotton-producing area. This area might be thought of roughly as the area extending one or two hundred miles on each side of the Red River and including the High Plains of Texas. In this area castor beans as a crop can compete with corn, peanuts or grain sorghum and can even compete with cotton if the grower gives as good care and uses as good land for castor beans as he does for his cotton crop. Instances of lower returns from castor beans than from cotton are usually traceable to the fact that the grower planted and cared for his cotton first and put castor beans on the "back forty" where he did not expect to produce a profitable yield of any crop.

The plant requires, under dry-land conditions, 150 to 180 days between the planting date and the first heavy frost in the fall. Production of maximum yields under irrigated conditions in California and Arizona requires a full growing season of about 270 days. A summer crop, however, is sometimes produced with somewhat lower yields in about 150 days, planting being in the middle of the summer and harvest being delayed until after the first freeze. Being of tropical origin, the crop tends to do best in an area where the temperatures remain fairly high during the entire growing season. The plants, however, may suffer from extremely high temperatures if accompanied by high winds as blasting of the flowers occurs following any severe wilting conditions. At least 15 to 20 in of summer rainfall are required for satisfactory yields under dry-land conditions and rainfall as low as this must be well distributed. Under irrigation, 3 to 3½ acre-feet of water applied at the proper time during the growing season will produce a good yield, the amount needed varying somewhat with local conditions. Although the castor bean crop will give fair response on many different soil types, best yields are obtained only on soils that have good drainage, no compact or impervious layers or clay pans, ability to warm up early in the spring, and good moisture-storage capacity.

AREAS OF ADAPTATION FOR CASTOR BEANS LIMITED

Present varieties are not grown in the Atlantic or Gulf Coast states because of damage from a destructive disease called gray mold, which attacks the flowering spikes and may destroy the entire crop; furthermore, when the crop is grown anywhere in the subhumid area of the eastern states, the pedicels that attach the capsules to the spike stem are so severely attacked by various fungi of the Alternaria species that the pedicels often break and thus cause severe loss from dropping. For these reasons, the areas of adaptation for castor beans do not at present include either the Atlantic or Gulf Coast regions or any other states east of the Mississippi River.

Castor bean varieties are classified as tall, which are grown under dry-land conditions; intermediate, which may be grown under both dryland or irrigated conditions; and short or semidwarf types, which are grown under irrigation in the Texas High Plains and in California and Arizona. Examples of these types are respectively, Conner, Cimarron and Baker 1. The differences in plant type of these various varieties, together with the varying behavior of any one variety under different soil and climatic conditions, are the main reasons for the need for further research on harvesting machinery which will be described here. Under typical dry-land conditions the Conner variety will produce from one to five spikes, the first being 2 to 4 ft from the ground, and later ones often being 7 or 8 ft high if moisture and fertility conditions are good. The first spike is the largest, and may well bear half the yield of a single plant. It is centrally located, while later spikes, borne on succeeding branches, will spread out from the central axis always being above the first spike. As the plant form tends to be upright, harvest by hand or a stripper harvester is relatively easy, except that considerable seed may be lost if the plant is jarred or shaken before being completely enclosed by the harvester. Some shattering may occur if the first spikes mature too long before frost permits mechanical harvesting.

The Cimarron plant is more desirable from the standpoint of yield and resistance to seed losses, but it is often more difficult to harvest because the first spike is closer to the ground and is always more or less protected by two or three branches which originate below the first spike and grow up around it. These branches, which may rebranch several times, also bear spikes, and the resulting bushy plant requires a wider opening in the front of a harvester. After frost, which is necessary for cheap defoliation, the branches soon become brittle, and attempts at forcing the plant into a small opening result in loss of seed.

The semidwarf types, of which the Baker strains and several of the latest USDA strains are typical, present the same problems as does Cimarron in a greater degree. They start to flower very close to the ground, often as low as 6 in, and branch and rebranch profusely. The seed is fairly easily removed if the plant can be cut off and put through a combine cylinder, but if many leaves remain at harvest, the central spikes are badly protected from the action of beater mechanisms. The proximity of the first spikes to the ground is obviously a problem.

Production of hybrid castor beans is now being investigated. It may be possible to combine high yield with more desirable plant type in the hybrids, as female inbreds now available have good stalk strength, spike size and desirable plant height.

Castor Bean Hulling Plants

(Continued from page 710)

hulling equipment could be such that only one vertical line of machinery is used. The total height of the hulling machinery would be approximately 40 ft. This would require heavier and more rigid supports with a head house built around the equipment.

The method and equipment for unloading of unhulled beans from wagons to hulling machinery is satisfactory at the present time and should be used at all plants. It is a very convenient method for unloading from all types of trailers and wagons and requires only a few minutes. The handling and disposal of hulls from beans and dust from equipment should be done in the regular manner as at the present time. Adequate equipment should be installed to prevent excess dust from entering the room in order to protect the health of workers.

Research Needs. Laboratory and shop work in testing existing huller and in developing new ones might open up several possible leads for improving machines for hulling castor beans. However, judging from observation and tests made during the 1951 season, attention might first be given to the following line of attack:

1 Erection and testing of a full-size hulling plant as outlined in Fig. 2.

2 Tests of performance of disk-type hullers with respect to (*a*) 18, 24 and 36-in-diameter disks, (*b*) disk surfaces, (*c*) angle of disk, horizontal to vertical, (*d*) disk speed, (*e*) relative hulling surface area, (*f*) cleaning mechanism, and (*g*) feeders.

3 Testing and the selection or development of efficient elevating and conveying equipment for hulling-plant use.

4 Equipment for picking up beans from floor of quonset and other structures where stored on ground levels.

5 Drying beans as received from farm. (*a*) Determine the fundamental factors involved and requirements for drying unhulled castor beans. (*b*) Develop suitable equipment of large capacity for drying unhulled castor beans at hulling plants for operation as beans are received during harvest.

6 Processing requirements to include handling, sampling and drying for storage of unhulled beans at central plant prior to hulling at a later date.

7 Removal of green immature unhulled beans.

8 Effect of handling operations on germination.

9 Development of equipment for removal of trash, rocks and other foreign material from mechanically harvested beans.

10 Adopt equipment for cleaning and treating seed stock.

An Experimental Castor Bean Huller

By J. G. Porterfield and F. J. Oppel, Jr.
ASSOCIATE MEMBERS ASAE

IN THE processing of castor beans, the castor bean huller plays an important part. The purpose of the huller is to remove and separate the hulls and trash from the beans without appreciable damage to the seed. It is important that this operation be done as completely and as efficiently as possible. Beans which are cracked lose oil and gradually become rancid. Trash, hulls, and cracked beans reduce the quality of the castor oil produced. Foreign materials and hulls contain no oil. They actually absorb oil during the extraction process. The presence of this extraneous material reduces the oil yield and imparts an objectionable dark color to the oil.

In 1942, H. A. Arnold and M. A. Sharp (1)* developed a vertical disk-type huller at the University of Tennessee. The machine consisted of two rubber disks, one stationary and the other rotating at approximately 1000 rpm. The rubber used on the disk faces was ⅜-in-thick, soft, abrasion-resistant sheet rubber with a specific gravity of 1.15. The disks were spaced about ½ in apart. This spacing allowed the beans to fit endwise between them without being crushed. A cleaning duct connected to a suction fan was provided to remove the cleanings. This 6-in machine hulled 95 to 98 per cent of the beans without appreciable cracking. The capacity was about 1 bu per hr. The capacity was found to be proportional to the area of the disks. Later in 1942 a huller was constructed with 12-in-diameter rubber-faced disks and vacuum-type cleaner. Rotating the disks at 525 rpm gave a capacity of 6 bu of hulled beans per hour with over 99 per cent hulled.

In 1942 H. P. Clay (3) built a castor bean thresher. The threshing device consisted of a 32 x 6, 10-ply truck tire slightly inflated and rotating at 50 to 100 rpm inside, approximately one-fifth of a 9.00 x 36-in tractor tire casing. The bead of the larger tire section was cut off and the remaining carcass mounted in a wooden frame. An air blast was used to separate the hulls from the beans. The capacity of this hulling element was over 200 lb per hr and with proper adjustment about 99 per cent of the beans were hulled.

In 1943 H. A. Arnold (2) designed an improved castor bean huller similar to the ones built in 1942. This machine had 24-in-diameter rubber-faced hulling disks, and an hourly capacity of 900 to 1400 lbs of shelled beans per hour. Because of its capacity it was known as the commercial size. A suction fan was employed to remove the hulls and trash from the clean beans. Under ordinary conditions the machine hulled from 95 to 98 per cent of the beans and those cracked were less than 2 per cent.

In Texas during 1941, E. D. Gordon (4) tried out several types of experimental hullers. One huller consisted of a horizontal cylinder 12 in in diameter and studded with steel spikes, ⅜ in in diameter and 2 in long. This cylinder rotated between a feeding hopper and a curved metal grate at about 250 rpm. The chaff was separated from the beans by the use of a screen and an air blast. This huller worked satisfactorily with some varieties of castor beans. However, excessive breakage occurred with the Conners variety.

Another huller that was tried consisted of an inverted conical rotor, mounted vertically and covered with rubber matting. The rotor turned inside a funnel-shaped housing lined with a smooth rubberized fabric underlain with a coating of ¾-in sponge rubber. No cleaning device was provided for this experimental unit. Rotor speeds ranging from 125 to 150 rpm cracked less than 1 per cent and hulled about 94 per cent. The capacity of this unit was considered low.

E. D. Gordon (4) built a small huller of the double-belt type in which two belts traveled parallel to each other and in the same direction. The top belt traveled 38 per cent slower than the bottom belt whose surface speed was computed to be 1200 fpm. The abrasive action of the belt surfaces traveling at different speeds removed the hulls from the beans, and tests showed that about 72 per cent were hulled and 2 per cent were cracked. The belt-type huller had a capacity of 650 to 700 lb of hulled beans per hour per foot of belt width.

E. D. Gordon (4) also investigated the possibility of using a small combine with a cylinder covered with heavy rubber matting. The cylinder was rotated at about 400 rpm and results showed that 85 to 90 per cent or more beans were hulled and 1 to 5 per cent were cracked; however, the Conners variety was badly damaged by the cylinder action. The machine had a capacity of 2,400 lb per hr.

A small huller was built by Gordon (4) in the winter of 1942. The hulling element consisted of a rubber-covered cylinder 8 in in diameter and 24 in long and a rubber-covered concave. The results showed that the Conners and Kentucky 38 varieties had less than 5 per cent cracked; however, the capacity was low. A paddle-wheel-type fan and rotary screens were

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Kansas City, Mo., June, 1952, as a contribution of the Power and Machinery Division.

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*Numbers in parentheses refer to the appended references.

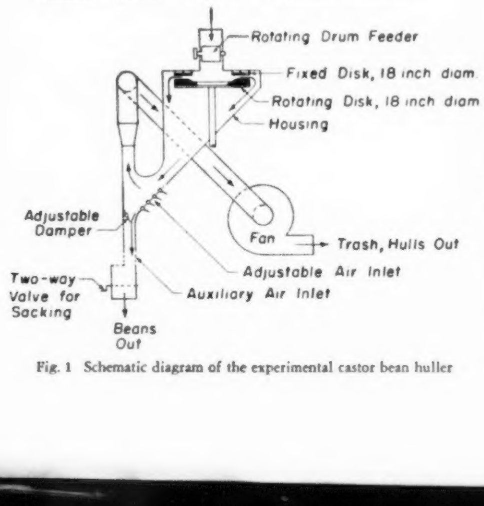

Fig. 1 Schematic diagram of the experimental castor bean huller

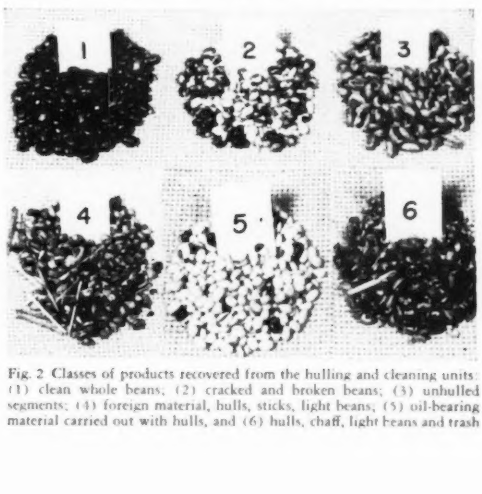

Fig. 2 Classes of products recovered from the hulling and cleaning units: (1) clean whole beans; (2) cracked and broken beans; (3) unhulled segments; (4) foreign material, hulls, sticks, light beans; (5) oil-bearing material carried out with hulls, and (6) hulls, chaff, light beans and trash

used for cleaning and separation.

This machine, using the cylinder-concave principle, was enlarged and became known as the "USDA Castor Bean Huller." The hulling unit consisted of a wooden cylinder 8 in in diameter and 24 in long with a concave facing covered with abrasion-resistant rubber matting having a durometer reading of 70. Separation and cleaning were accomplished by a vibrating screen and suction-type fan. The vibrating screen was equipped with a reciprocating wiping device to prevent clogging and to aid in separation of unhulled from hulled beans. The hulling cylinder had a capacity of 1,200 lb per hr. Five of these machines were built during the 1942-43 hulling season.

This huller was later improved by development work at the U.S. Tillage Machinery Laboratory at Auburn, Ala. Simplification of this unit resulted in an improved huller with a capacity of between 1,600 and 1,850 lb per hr, and under normal conditions the cracked beans were less than 2 per cent and 98 per cent were hulled.

J. C. Wooley and R. P. Beasley (5) worked on castor bean hullers from 1939 to 1942. Their most satisfactory huller consisted of a cylinder and concave 40 in long, covered with rubber matting. The concave was also rubber covered. The regular combine cylinder was set to knock the capsules from the spike. The capsules were then brought to the hulling cylinder by the tailings elevator. After hulling, the beans and hulls were separated by the regular combine screens and the beans elevated to the grain tank.

THE EXPERIMENTAL CASTOR BEAN HULLER

When a study was made of previous castor bean hullers, it was found that no work had been recorded on a castor bean huller with a horizontal disk. From close analysis of the problem, it was believed that there were certain merits to the horizontal disk-type huller that would make it desirable. With this in mind, the experimental huller described in this paper was designed and built with the cooperation of engineers and agronomists of the U.S. Department of Agriculture. A schematic diagram of this huller is shown in Fig. 1. The complete unit consists essentially of a hopper and an elevator unit with separate electric-motor drive, a rotary-drum feeder, a hulling element consisting of two horizontal adjacent rubber-faced disks driven by a separate engine, and a cleaning unit made up of a suction fan powered by a separate engine. Any one of these units can be adjusted independently, thereby making it possible to adapt the huller to various conditions to get maximum effectiveness and efficiency.

The engine on the huller was rated at 4.3 hp. The huller element consists of two adjacent rubber-faced disks. One of the disks is stationary and one rotates. The rotary disk is attached to the end of a vertical shaft driven by the huller engine. The rotary disk has an outside diameter of 18 in and is faced with one-inch thickness of soft, abrasion-resistant rubber with a durometer hardness varying with the test. (All durometer hardnesses are based on company specifications and not on actual tests at the time the rotary disk is used.) The rubber is cemented to a ¼-in steel plate with rubber cement. The hulling surface of the rotary disk lies between a 14-in diameter and an outside diameter of 18 in. It consists of an area of about 100 sq in. The rubber-disk facing on the rotary disk is provided with a one-inch bevel at the center opening. The inner edge of the bevel is protected from being torn loose by a 1/16-in steel plate fastened to the ¼-in plate by machine screws. This bevel is essential to break up the whole capsule into single segments small enough to enter the hulling space, to guide the beans between the disks, and to increase the capacity of the machine. Careful consideration was given to selecting the bevel since too much bevel would overload the disk, increase the amount of cracked seed, and permit large foreign objects to go between the disks.

The fixed disk is attached to the lower side of the top plate of the huller housing. The fixed disk has an outside diameter of 18 in and is faced with a ¼-in thickness of rubber with a durometer hardness varying with the particular test. The rubber is cemented to the ¼-in steel plate which is fastened by four bolts to the top of the huller housing. No bevel is provided on the fixed-disk rubber facing. A sheet metal back is fastened around the inside and outside diameters of the fixed-disk housing to prevent the material from wedging and passing between the huller housing and the fixed disk.

The spacing between the disks is adjusted by moving the rotary disk and vertical shaft assembly by means of a small threaded hand wheel in the front of the huller. Turning the threaded hand wheel slides the assembly up or down on four supporting bolts. Once the spacing is set it remains fixed since no provision was made on this machine to prevent damage to the disk whenever a large object entered the disk.

Alignment of the disks is provided on the fixed disk by means of four adjustable screws equally spaced on a square centered on the main diameter of the fixed disk. The screws may be raised or lowered by turning them inside the four nuts welded to the top plate. By raising or lowering the screws and tightening the four bolts fastened to the fixed disks, the proper disk alignment is attained.

The rotary-drum feeder is a wooden roller 5 in in diameter. The feeder and its housing are fastened over the central opening on the top plate. Its primary function is to facilitate uniform feed of the beans to the huller disk. The rotation of the moving disk automatically feeds the beans onto the hulling surfaces, breaking the capsules, removing the hulls and discharging the hulls and beans at the periphery. The feeding of the beans centrally between the disks causes the layers to spread out as the beans move outward, thus reducing the chances of wedging.

The cleaning unit uses a centrifugal fan. It is driven by a 2-hp motor. The fan is 22 in in diameter and connected with

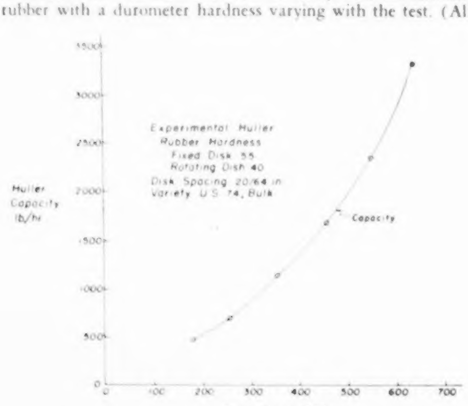

Fig. 3 The effect of huller disk speed on huller capacity

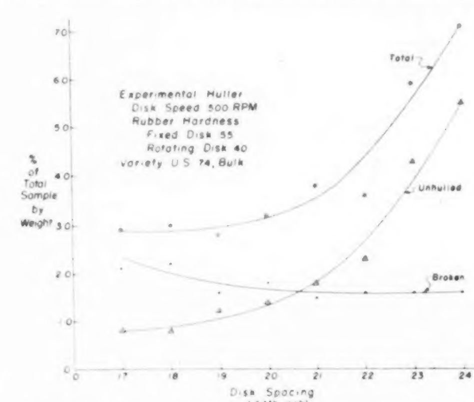

Fig. 4 The effect of huller disk spacing on broken and unhulled beans

an 8-in suction pipe to the housing. The suction line is connected to the Y cleaning duct, which has a cross section of 3 in by 20 in. The Y cleaning duct is equipped with an adjustable damper at the upper end to furnish restriction on the air inlet, yet permit sound, whole beans to drop through the throat area against an upward air stream and then into the sack. The damper permits varying the cross-sectional area from zero to 2 in in width. Additional air inlet is provided by a screened area of 4 in by 20 in which may be adjusted by four shutters, each one inch by 20 inches, so that an additional air velocity is available to carry off the hulls. By closing one of these shutters, an increase in fan speed may not be required. The mixture of hulls, beans, and unhulled beans slides down a short incline from the hulling disk to the Y cleaning duct. The hulls, dust and light, undeveloped beans are carried up with the air through the fan, which discharges them to the outside. The clean, whole beans drop through the throat area and are sacked at the discharge spout. This spout is equipped with a two-way valve to facilitate sacking operations.

Fig. 2 shows several distinct classes of products sampled from the hulling and cleaning units.

PERFORMANCE AND RESULTS

Speed. The speed of the rotating disk in the experimental huller was varied from approximately 180 to 650 rpm. The results of these tests, as shown in Fig. 3, indicate that as the speed increases, the capacity increases throughout the entire range tested. As the speed increases the percentage of unhulled segments and the percentage of cracked beans increases. Fig. 5 shows the influence of speed on these factors. In actual operation, it is desirable to have the maximum capacity on the huller. If the speed is increased to the point of maximum capacity, the percentages on unhulled beans and cracked beans will be higher than could be tolerated. On the basis of tests with the experimental machine, it appears that with this type of machine there must be a compromise between maximum capacity and minimum breakage and unhulled beans.

Spacing. Since all of the tests that were run on this experimental machine were with one variety of beans (US 74), the results may not be applicable to another variety. In general, the effect of spacing is evident when the data are studied. As would be expected, there is some spacing below which the performance of the huller is unsatisfactory. On the basis of the results shown in Fig. 4, it appears that between 20/64 and 21/64-in clearance between the disks provides the optimum compromise as far as capacity, cracked and unhulled beans are concerned. As the spacing increases the number of cracked beans decreases, but the number of unhulled beans increases rapidly. It may be that the spacing should be increased to 23/64 or 24/64 in and provision made for recirculating the unhulled beans that pass through the disks. This might increase the capacity of the huller without sacrificing its efficiency. Below the spacing of 20/64 or 21/64 in the capacity drops rapidly and the number of cracked beans increases; however, the number of unhulled beans decreases rapidly as the spacing drops below optimum.

Rubber Hardness. All rubber hardnesses were taken from company specifications and were used as such during the testing period. Later tests were made on the hardness of the rubber and there was found to be some variation from the company specification. It is not known whether these lie within the tolerance allowed by the company or not. Several combinations of rubber hardness were tried on both the fixed and rotating disk: 30, 40, 55, and 70 durometer. The hardnesses of rubber used on the rotating disk were 30 and 40 durometer. These were used in several different combinations. Although the tests are not as extensive as might be desirable, certain inferences can be taken from the data. It appears that a difference in hardness between the fixed and the rotating disk of approximately 15 points gives the best performance, considering the maximum capacity and the minimum unhulled and cracked beans collectively. It is apparent from the results shown in Fig. 6 that other combinations may give fewer cracked beans, but the capacity is lower. It also appears that a durometer hardness in the range between 30 and 50 with the spacing specified will give the best over-all results. It is recognized that many other variables may enter into this, such as the beveled edge, the heights of the rubber, the alignment of the disks, and others.

Other Variables. Additional testing will be required on this machine to determine the relationship of other factors to the performance of the huller. Such factors as moisture content, trash content, the influence of the cleaning unit, fan speed and air movement may also be important in the over-all performance.

It is anticipated that a larger hulling unit built on this same principle will be ready for use before the 1952 hulling season. Additional tests will be made on the variables already studied and on others that have not been studied to date.

SUMMARY

An experimental castor-bean huller with 18-in-diameter disks rotating in a horizontal plane was built and tested the past year. The principle of the horizontal disk is different than the other machines that have been built previous to this time for castor-bean hulling. The experimental machine was built so that the spacing between the disks, the type of rubber on the disks, the speed of the disks and other variables could be regulated and controlled. An increase in speed resulted in an increase in capacity, an increase in unhulled beans, and an increase in cracked beans. The spacing which has been optimum for the particular variety of castor beans (US 74) used in this test is between 20/64 and 21/64 in. As the spacing becomes less than this, the number of unhulled beans decreased but the number of cracked beans increased considerably. As the spacing was increased above this apparent optimum, the unhulled beans increased and the *(Continued on page 716)*

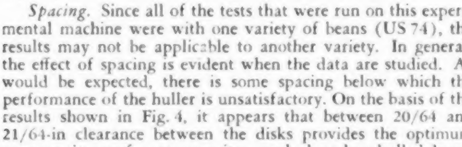

Fig. 5 The effect of huller disk speed on broken and unhulled beans

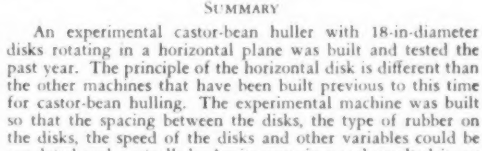

Fig. 6 The effect of hardness difference of the hulling disks on capacity and cracked and broken beans

The Small-Dam Program in Flood Control

By L. S. Terbush

IN THE Flood Control Act of 1944, the U.S. Department of Agriculture was authorized to start an operations program in the Washita River watershed (Oklahoma and Texas) for runoff and waterflow retardation and soil erosion prevention. The program includes watershed treatment, consisting of improved cropping and other management practices, land-use adjustments, soil and water conservation practices and works, and various combinations of such measures; and upstream floodwater retarding structures and appurtenant measures primarily for waterflow retardation.

The Washita River rises in the Panhandle of Texas and flows for some 650 miles in an easterly and southeasterly direction across the south and central part of Oklahoma. It empties into Lake Texoma near Tishomingo in Johnston County, Oklahoma. The watershed is about 300 miles long and varies in width from 25 to 50 miles. The total drainage area, 7,961 square miles (5,095,040 acres), includes 97 square miles inundated by the Washita arm of Lake Texoma.

In planning our operations we have divided the Washita River into 64 creek watersheds varying in size from 27 to 680 square miles. It was found that approximately 112,000 acres of bottomland lie along the main stem of the river, while these creek watersheds contain some 265,000 acres of flood plain. So far as we have been able to determine, no one flood has covered all of the main stem bottomland. The highest frequency of flooding along any reach of the main stem is slightly in excess of two floods per year. However, the creek watersheds which contain 70 per cent of the bottom land, have a high frequency of flooding. They average from two to six damage-producing floods per year. One thing then is clear. The most important job is the reduction of floodwater and sediment damages in the tributary watersheds — the 64 creeks which make up the Washita River.

To date we have completed engineering surveys on twenty of these creek watersheds comprising 1,850,882 acres.

This paper is confined to a discussion of one of these watersheds in which all of the planned structures and measures are now being completed. This watershed, Sandstone Creek, is located in the upper third of the Washita River watershed and lies wholly in the Rolling Red Plains. Its area is approximately 100 square miles.

The economy of the watershed is agricultural, beef cattle production and dairying being the major enterprises. Ninety per cent of the cultivated bottom land and 70 per cent of the cultivated upland is used for feed crops. Cotton and wheat are raised as cash crops.

Progress on the land-treatment portion of the program is excellent. One hundred twenty-seven farm and ranch owners and operators are cooperating with local soil conservation districts in applying land-treatment practices. These farms and ranches comprise more than 90 per cent of the watershed area.

Needed land-treatment measures include 433 miles of terraces along with some 50 acres of farm waterways, seeding of 5,800 acres of idle or abandoned land, 17 miles of farm diversions, 125 farm ponds, and 49 miles of fencing to enclose newly reseeded areas. The estimated total cost of installing these measures is $533,107, and the annual cost, including installation and maintenance, is $16,961.

All storms that occurred during the 1920-39 period, inclusive, were studied, and 59 floods were routed through the watershed.

Damages from these storms were calculated considering both the season and the depth of flooding. Land-use and crop-damage information was obtained from farm operators in the flood plain area. Road and bridge damages were reported by the board of county commissioners of Roger Mills County.

It was found that floodwater and sediment damages on the 4,700 acres of bottom land amounted to $58,697 annually for the 20-year period.

The floodwater retarding measures planned for the watershed include 24 detention structures, 17 drop inlets located above the detention structures for gully stabilization and sediment control, 1.3 miles of floodwater diversions for increasing the drainage areas of the detention structures, and one mile of floodway. The estimated total cost of installing these measures is $1,153,729. The annual cost, including installation and maintenance, is $36,982.

The land-treatment measures and the dentention structures will reduce the average annual flood damage from $58,697 to $1,236, an annual benefit of $57,461. Most of this reduction will be effected by the system of floodwater retarding structures. The structures and appurtenant measures are expected to provide a total of $54,518 (93 per cent) annual benefit.

In addition to the benefit from reduction of damages, farm operators in the flood plain indicated that they will intensify their farming operations by growing a larger proportion of high-value crops. It was estimated that an annual net benefit of $11,019 will result from conversion of flood plain land to more intensive use.

The total waterflow retardation benefits from reduction in flood damages and more intensive use of the flood plain are estimated to be $65,537. In addition, it is estimated that the benefit to landowners and operators in upland areas of the watershed from the application of land-treatment measures will be $88,039 annually.

Comparison of Cost and Benefits. The average annual benefit of $65,537 from floodwater retarding structures compared with the average annual cost of $36,982 for these measures represents a benefit of $1.77 for each dollar of cost.

The ratio of the average annual benefit of $90,982 from the land-treatment measures and practices to their average annual cost, $16,961, is $5.36 of benefit for each dollar of cost.

The ratio of the total average annual benefit of $156,519 to total average annual costs, $53,943, is $2.90 of benefit for each dollar of cost.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1951, as a contribution of the Soil and Water Division.

The author: L. S. TERBUSH, flood control engineer, Soil Conservation Service, U.S. Department of Agriculture, Chickasha, Okla.

Castor Bean Huller

(Continued from page 715)

cracked beans decreased. The capacity of the machine obviously increases as the spacing between the fixed and rotating disk increased. The rubber-faced disks which seem to give the best performance were ones which had a difference in hardness between the fixed and rotating disks of 15 durometer points. As the difference in rubber hardness increased, the capacity of the machine decreased and the cracked and unhulled beans increased. As the difference in rubber hardness decreased, the capacity decreased. Other factors which may be important in the performance of the castor-bean huller are the moisture content of the beans, the type of cleaning equipment, the variety of beans, the amount of trash and foreign material in the beans to be hulled, and other factors which have been mentioned but were not studied.

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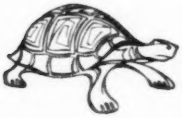

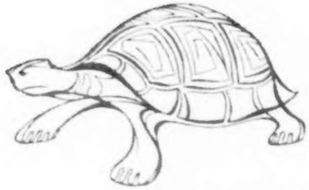

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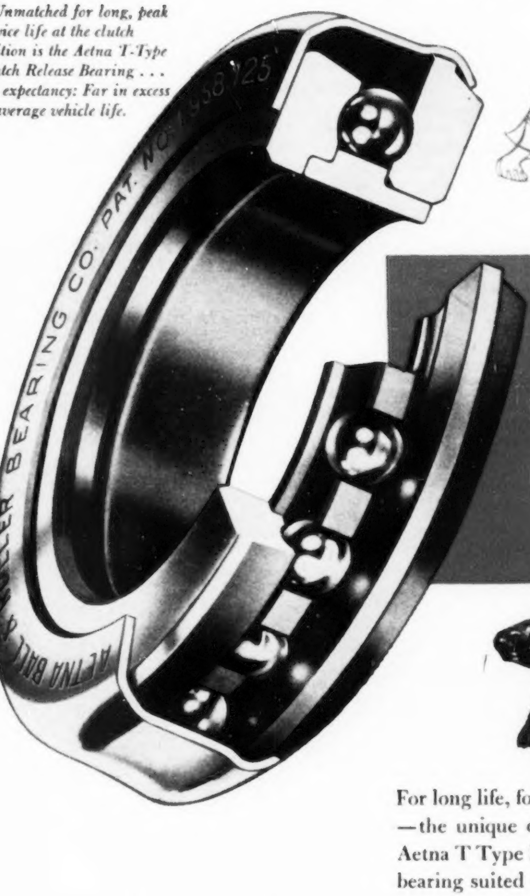

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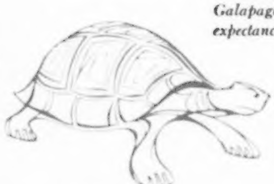

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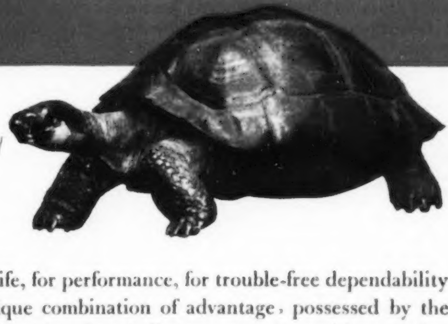

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INSTRUMENT NEWS

KARL NORRIS, Editor

Contributions about interesting agricultural applications of instruments and controls, and related problems, are invited, and should be sent direct to K. H. Norris, Agricultural Research Center, Beltsville, Maryland.

A Method of Increasing the Latitude of a Recording Potentiometer

By C. M. Hansen and Carl W. Hall

IN A temperature study, it is sometimes necessary to record the temperature of a large number of thermocouples on a recording potentiometer. Frequently the number of thermocouple connections on the potentiometer are fewer than the number of thermocouples that are to be read. It is possible to manually shift the potentiometer contacts from one set of thermocouples to another, but this is laborious and does not lend itself to continuous recording for several days.

In the agricultural engineering department at Michigan State College an 8-point recording potentiometer (Brown, Model No. 153X60P8-X-31F1) is used for recording automatically the temperature of 52 individual thermocouples. A rotary stepping switch which by-passes the regular 8-point switch in the potentiometer makes the recording possible (Fig. 1). The potentiometer and stepping switch should be calibrated for accurate readings. Special low-resistance stepping-switch wipers and contacts may be obtained at a considerable increase in cost. One thermocouple in the series was placed next to a light bulb. Its high reading among the lower readings served as an indexing point for separating successive series of readings.

Stepping Switch. The ratchet-type stepping switch for the three banks of 26 terminals, including three wipers, is fixed on a shaft driven by a pawl-and-ratchet mechanism (Figs. 1 and 2). Contact number 26 is completed mechanically in proper sequence by a projection from the wiper drive shaft to a spring contact as identified in Fig. 2. Only eighteen of the 26 terminals were used in the third bank of terminals. Terminal box a, b, c, d is a part of the original switch assembly provided for external connections. The internal connections from terminal box to a, b, c, d are complicated and have been omitted for simplicity. For details of the internal operation of the rotary stepping switch, consult the reference listed*. The pawl-and-ratchet mechanism which turns the shaft and the attached wipers, is actuated by an electromagnet which responds to momentary current impulses. At each impulse the pawl engages the ratchet, moving the three wipers one step over the three sets of contacts. The three wipers and three sets of contacts are schematically represented across the bottom of Fig. 1. The rotary stepping-switch assembly, Type 45, Part No. S 3 BDC, is manufactured by the Automatic Electric Co., and is distributed and sold by the Automatic Electric Sales Corp. of the same address. It is commercially produced for a dial telephone in addition to other electrical controls. It is necessary to make only the external connections to the stepping-switch assembly to adapt it for use on the potentiometer, as shown in Fig. 2.

Fig. 1 illustrates the connections between the stepping-switch assembly, located inside the control box, and the external connections from the control box. It is not a wiring diagram. A maximum of 52 thermocouples can be connected at the numbered connections. Numbers 1 through 52, letters *A* through *T*, P_1, P_2, *Cu*, *Const.*, X, and the 115-v leads represent external connections to the control box containing the stepping-switch assembly.

Wipers for the first and second banks of contacts are located at 180 deg from each other. The wipers of the third bank of contacts consist of two arms at 180 deg with each other which are in continuous contact with the terminals. After the wipers in the first bank complete contacts through 26, the second wiper, which is at 180 deg, goes to contact 27, then on to contact 52. After this, the wipers are in a position to repeat the cycle.

The constantan knob in the connection panel of the control box was installed as a matter of convenience for holding the wire on its way to the recording potentiometer. The copper connection is represented by (+). Plug-in terminals, P_1 and P_2, connect to and actuate the temperature and printing mechanism at the top rear of the hinged door of the Brown potentiometer. The chart drive on the bottom rear of the hinged door is connected directly to 115 v. A Galvin condenser 8A 31232C (5-200 v) was connected in parallel across the 115-v circuit to provide adequate spark suppression (see reference).

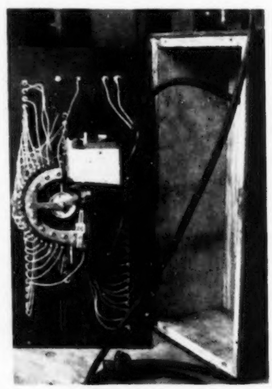

Fig. 2 External connections to stepping switch

The lettered connections, *A* through *T*, are used for a cancelling circuit when less than 52 readings are to be taken (Fig. 1). When *A* and *B* are shorted out by connecting *A*, *B*, and X by a copper conductor, it is impossible to get readings on the corresponding positions of the other contact points to terminals 1, 27, 2, and 28; thus 48 thermocouple readings can be made. When reading 16 thermocouples, 36 thermocouple terminals would have to be shorted out. To short out 36 thermocouple terminals, 18 terminals of the cancelling circuit would have to be connected together and shorted out to X. The wipers will then automatically slide through these points and come to rest in a position to begin the readings as desired.

This paper was prepared expressly for AGRICULTURAL ENGINEERING and is approved for publication by the Michigan Agricultural Experiment Station as Article 1344.

The authors: C. M. HANSEN and CARL W. HALL, assistant professors of agricultural engineering, Michigan State College.

*Rotary Stepping Switches, Bulletin 473, Automatic Electric Co., 1033 W. Van Buren St., Chicago 7, Ill., 1951.

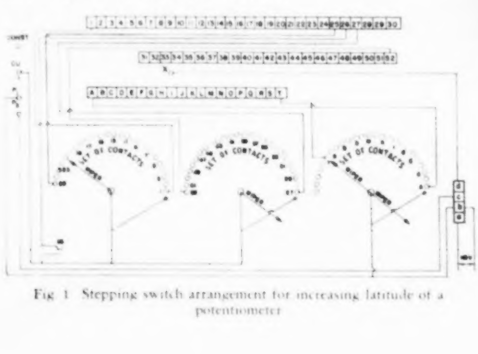

Fig. 1 Stepping switch arrangement for increasing latitude of a potentiometer

A Recorder Switching Circuit

A SWITCHING circuit for providing up to 32 recording points with a 16-point recorder is described in an article, entitled "Multipoint Recording," by John G. Taylor, in the publication *Instruments* for August, 1952, vol. 25, page 1080.

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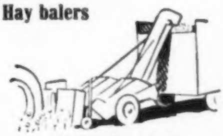

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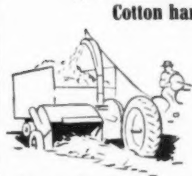

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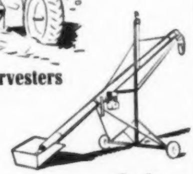

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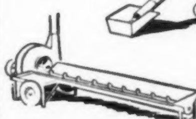

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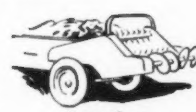

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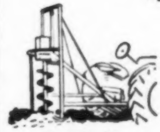

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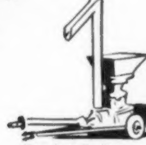

Feed grinders

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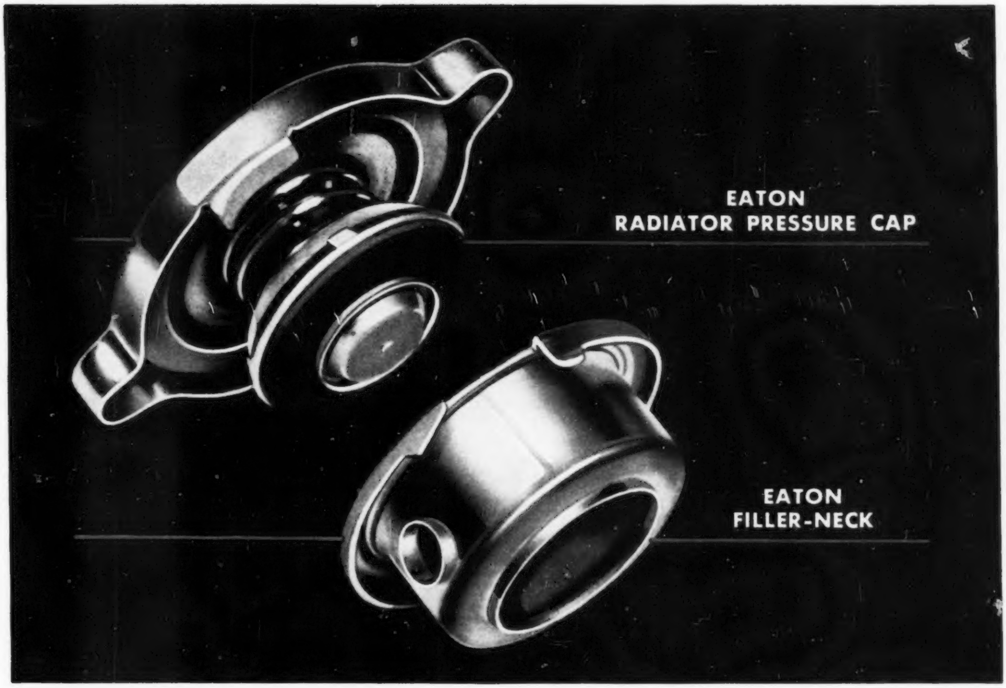

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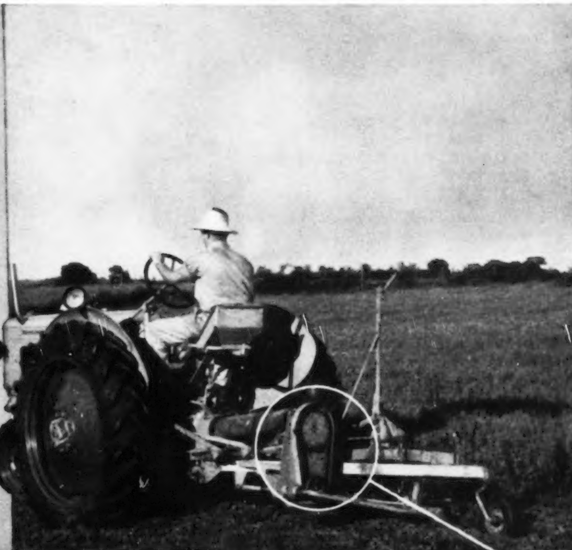

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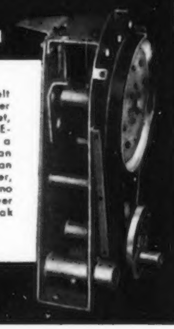

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(Continued from page 722)

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Committee on Feed Handling—H. C. Rutt (chairman), H. S. Hinrichs, W. G. Buchinger, R. E. Johnson, L. S. Foote, P. L. Lyman, B. P. Hess, J. H. Oliver, B. A. McKenzie, L. A. Brooks, T. O. Hodges, M. W. Forth, I. P. Blauser, C. K. Otis, L. S. Singley

Committee on Heat Lamps for Brooding—R. E. Heston (chairman), W. D. Hemker, J. M. Stanley, W. J. Ridout, Jr., W. G. Buchinger, C. L. Hamilton, S. J. Marek, V. H. Baker, J. P. Ditchman

Committee on Hay Harvesting and Storage (Joint with Power Machinery and Farm Structures Divisions—see listing under Power and Machinery Division)

Committee on Crop Drying Equipment (Joint with Power and Machinery Division—see listing under Power and Machinery Division)

Committee on Animal Shelter Ventilation (Joint with Farm Structures Division)—H. N. Stapleton (chairman), H. J. Thompson, C. G. Burress, R. G. Ferris, Nolan Mitchell, M. H. Lloyd, T. E. Long

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N. H. Curry, vice-chairman
C. K. Otis, junior past-chairman

Executive committee—D. B. Poor (chairman), N. H. Curry, C. K. Otis

Committee on Dairy Housing Terminology—Thayer Cleaver (chairman), H. N. Stapleton, K. W. Hotchkiss, W. F. Keepers, B. T. Stephanson, G. H. Dunkelberg, G. D. Kite, L. W. Neubauer, B. F. J. Cargill

Committee on Hay Harvesting and Storage (Joint with Power and Machinery and Rural Electric Divisions—see listing under Power and Machinery Division)

Committee on Crop Drying Equipment (Joint with Power and Machinery and Rural Electric Divisions—see listing under Power and Machinery Division)

Committee on Animal Shelter Ventilation (Joint with Rural Electric Division—see listing under Rural Electric Division)

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A. J. Wojta, vice-chairman
R. R. Poynor, junior past-chairman

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Steering Committee—R. R. Poynor (chairman), R. B. Hickok, J. G. Sutton, E. H. Kidder, A. J. Wojta, R. M. Merrill, W. D. Criddle, G. E. Ryerson, J. R. Carreker

Committee on Rural Water Supplies—E. L. Arnold (chairman), Roy Lundquist, R. S. Leach, G. E. Trisler, E. R. Daniel, M. W. Clark. *Subcommittee on Water Conditioning* (chairman), E. A. Olson, S. J. Marek

Committee on Erosion Control—J. H. Lillard (chairman), D. D. Smith, R. P. Beasley, J. R. Carreker, R. C. Hay, E. H. Kidder, A. W. Zingg, M. B. Cox, Edwin Freyburger, D. O. Hull. *Subcommittee on Terrace Specifications*—R. C. Hay (chairman), J. R. Carreker, M. B. Cox, D. O. Hull, A. J. Wojta, J. F. Schrunk

Committee on Mechanical Applications of Soil Conservation Practices—A. J. Wojta (general chairman). *Subcommittees*: (1) *Contour Strip Cropping*—D. H. Daubert (chairman), A. T. Hendrix, C. B. Richey; (2) *Surface Drainage Systems*—K. H. Beauchamp (chairman), J. W. Borden, H. N. Holtan, V. B. Coxworth, H. B. Atkinson; (3) *Terrace Systems*—H. B. Atkinson (chairman), R. B. Hickok, W. H. Lowry, E. W. Schroeder; (4) *Mulch Tillage*—J. H. Lillard (chairman), L. J. Harrold, G. E. Ryerson, J. F. Schrunk

Committee on Drainage—J. G. Sutton (general chairman). *Subcommittees*: (1) *Depth and Spacing of Tile Drains*—R. K. Frevert (chairman), K. H. Beauchamp, T. W. Edminster, H. N. Luebcke, W. W. Donnan, G. O. Schwab, W. F. Lytle, C. L. Larson; (2) *State Drainage Laws*—I. D. Mayer (chairman), R. C. Hay, A. Carnes, R. W. Carpenter, O. W. Israelsen, P. W. Manson, Virgil Overholt, E. G. Welch; (3) *Drainage of Irrigated Lands*—James Turnbull (chairman), C. R. Maierhofer, R. C. Reeve, W. W. Donnan, E. A. Olafson; (4) *Drainage Equipment*—I. L. Saveson (chairman), J. I. Davis, Sr., G. E. Ryerson, T. W. Schultz, K. H. Beauchamp; (5) *Specifications for Design and Construction of Tile Drainage*—K. H. Beauchamp (chairman), G. O. Schwab, F. F. Shafer, Virgil Overholt, C. L. Larson, J. H. Lillard, E. W. Gain, K. W. Hotchkiss, H. F. Peckworth, W. A. Cutler; (6) *Quality Requirements of Draintile*—P. W. Manson (chairman), C. L. Larson, Paul Jacobson, W. S. Lynes, B. F. Muirheid, K. K. Barnes, E. H. Kidder, W. W. Donnan, H. M. Ellis, Phelps Walker

Committee on Irrigation—W. D. Criddle (general chairman). *Subcommittees*: (1) *Sprinkler Irrigation*—M. W. Hoisveen (chairman), W. W. Hinz, F. N. Johnson, A. W. McCulloch, R. M. Morgan, F. W. Peikert, Crawford Reid, A. S. Marlow, Jr., F. W. Boynton, J. E. Christiansen (advisory), F. E. Price (advisory); (2) *Sprinkler Irrigation Research*—E. H. Kidder (chairman), Crawford Reid, M. W. Hoisveen, Arthur King, F. W. Peikert, C. H. Pair

Committee on Soil Tilth (Joint with Power and Machinery Division—see listing under Power and Machinery Division)

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L. W. Hurlbut, vice-chairman
E. W. Schroeder, junior past-chairman

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Committee on Agricultural Teacher Training—C. F. Albrecht (chairman), V. J. Morford, M. M. Jones, E. W. Foss, A. H. Hollenberg, G. E. Henderson, C. N. Hinkle. *Advisory Group*: H. B. Swanson*, H. W. Kitts*, D. R. McClay*, David Hartzog*, T. J. Wakeman*

Committee on Graduate Instruction—F. W. Peikert (chairman), W. M. Carleton, M. L. Esmay, O. C. French

Committee on Course Content—L. W. Hurlbut (chairman), R. K. Frevert, J. W. Martin, W. M. Carleton, A. C. Dale, R. L. Perry

Committee on Youth Activities—C. M. Edwards (chairman), G. W. Ginger, D. O. Hull, J. L. McKitrick, R. T. Scott, C. L. Hamilton

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*Indicates non-member of ASAE

A Correction

ATTENTION of readers is called to errors in the summary of the paper, entitled "Factors in the Design of Baled-Hay Driers" by V. H. Baker and J. L. Calhoun, beginning on page 627 of the October, 1952, issue of AGRICULTURAL ENGINEERING. The errors are confined to paragraph 5 in the Summary on page 651. As corrected this paragraph should read as follows:

> 5 For design purposes, a 14 x 18 x 36-in bale of alfalfa hay at 20 per cent moisture can be considered to weigh 45 lb, occupy about 6.65 cu ft and cover 4 sq ft of area when stacked on edge. The 16 x 18 x 36-in bale at 20 per cent moisture weighs about 50 lb, occupies about 7.50 cu ft, and covers about 4.60 sq ft of floor space when stacked on edge. A rule-of-thumb method for estimating the space occupied by baled hay is to use a figure of 300 cu ft per ton.

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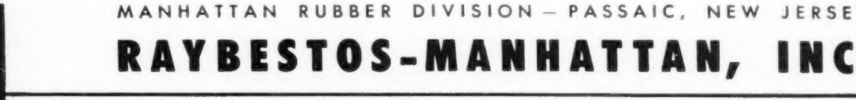

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NEWS SECTION

Iowa-Illinois Section Program

THE Iowa-Illinois Section of the American Society of Agricultural Engineers will hold its fall meeting on Friday, November 14, at the East Moline (Ill.) Works of the International Harvester Co.

Registration will begin at 12:30 p.m. in the main lobby of the Company's works, and tours of the plant will be made during the early afternoon. At 4 p.m. the motion picture "Inside Harvester" will be shown in the American Legion Club Room in East Moline.

The Section dinner will be held in the Legion Club Room at 6:30 p.m., and the program that follows will include a talk on industrial education and training for today's problems by E. H. Reed, manager of education and personnel, IHC. F. I. Fuller, general supervisor of material research, IHC, will talk on the effect of manufacturing research on farm implement machinery.

Georgia Section Meets November 14

THE Georgia Section, ASAE, will hold its fall meeting at Radium Springs near Albany, Ga., on November 14. The forenoon session will be opened by Section Chairman John T. Phillips, Jr., following which the group will be welcomed to Radium Springs by J. Irwin Davis, Sr. The formal program of the session will start with a talk on highway life insurance by Bill Blunt of the Georgia Power Co. He will be followed by Ed Komarek of Greenwood Plantation discussing the corn industry and its challenge to agricultural engineers. An approach to pasture development is the subject of a talk by J. Irwin Davis, Jr., and the challenge of farm management to agricultural engineers will be the subject discussed by Leslie Abersold.

This program will be followed by a luncheon at the Radium Springs Casino after which the group will tour the Clark Thread Company's plant, referred to as the world's most modern cotton thread processing plant.

The first two speakers on the afternoon program are George B. Nutt and Fred A. Kummer, respectively, heads of the agricultural engineering departments of Clemson Agricultural College and Alabama Polytechnic Institute. They will report on the agricultural engineering work in their respective states. Following these two talks, a panel of speakers with R. H. Driftmier as moderator will handle all informal questions and answers based on talks featured on the forenoon and afternoon program.

The meeting will close with a barbecue on the Radium Springs grounds.

Oklahoma Section Fall Meeting

THE Oklahoma Section, ASAE, will hold its annual fall meeting on November 28 at the Student Union Building on the campus of Oklahoma A. & M. College in Stillwater. The technical program beginning at 10:00 a.m. will include talks by W. Elmo Baumann on "Impervious Soil Problems"; "Engineering Phases of Castor Bean Production," by Leonard G. Schoenleber; "Development of Pole Barn Design and Construction Principles" by Roy E. Hayman, and "Training Engineers in the Farm Equipment Industry," by the Oklahoma City Tractor Club and R. E. Jacquier.

At noon, Oklahoma Section members, their guests, and wives will dine together at an Oklahoma Section luncheon. During the luncheon hour Mr. Leon J. McDonald of the USDA Soil Conservation Service will present a slide film talk, entitled "The Fifth Plate."

The afternoon program to be presided over by C. V. Phagan will include two discussions on the "where" and "how" phases of irrigation in Oklahoma by Robert B. Duffin and James E. Garton, respectively. The final item on the technical program is to be a discussion by Carl Ferguson on "The Agricultural Engineer in Rural Electrification."

The Oklahoma Section will hold their annual business meeting at three o'clock in the afternoon at which time officers for the ensuing year will be elected and other business transacted.

Section officers for the year 1951-52 include Maurice B. Cox, chairman, W. T. Wheeler, vice-chairman, and G. L. Nelson, secretary-treasurer.

Irrigation Theme of West Virginia Meeting

A TWO-DAY meeting of the West Virginia Section of the American Society of Agricultural Engineers, at Jackson's Mill, November 7 and 8, concentrated its attention on various aspects of irrigation.

Subjects scheduled included water sources and supply, water storages, water law problems, crops and soils for irrigation, irrigation equipment and power units, irrigation sprinklers, designing irrigation systems, and planning and preparing irrigation system specifications. An inspection trip to a nearby farm provided opportunity for practice in the application of principles to the development of a system to fit a specific situation.

ASAE Meetings Calendar

November 14—GEORGIA SECTION, Radium Springs, Albany, Ga.

November 14—IOWA-ILLINOIS SECTION, International Harvester Works, East Moline, Ill.

November 28—OKLAHOMA SECTION, Student Union Bldg., Oklahoma A. & M. College, Stillwater

December 15-17—WINTER MEETING, Edgewater Beach Hotel, Chicago, Ill.

January 23 and 24—NORTH CAROLINA SECTION, Reddick Auditorium, Raleigh, N. C.

February 9-11—SOUTHEAST SECTION, Roosevelt Hotel, New Orleans, La.

February 14—MICHIGAN SECTION, Edison Boat Club, Detroit, Michigan

June 15 to 17—46TH ANNUAL MEETING, Hotel William Penn, Pittsburgh, Pa.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Michigan

Best New Chairman Pennsylvania Section

ALBERT M. BEST, research engineer, New Holland Machine Division, The Sperry Corp., was elected the new chairman of the Pennsylvania Section of the American Society of Agricultural Engineers for the ensuing year at the Section's regular fall meeting held October 9 and 10 at the Penn Wells Hotel in Wellsboro, Pa. Harold V. Walton, assistant professor of agricultural engineering, Pennsylvania State College, who has been serving the past year as secretary of the Section, was elected the new vice-chairman. The new secretary elected at the meeting is James B. Kistler, assistant superintendent of farms at Pennsylvania State College.

The program of the meeting featured the rural electrification and farm machinery phases of agricultural engineering and included the subjects of farm refrigeration, mow hay finishing, barn ventilation, standby power generators, forage harvester versatility, economics of farm machinery and chemical weed control. At the close of the first-day session the group visited Pennsylvania's Grand Canyon a short distance from Wellsboro, and at the conclusion of the program on the second day they took an organized trip to Corning, N. Y., to visit the plant of Corning Glass Co.

A year ago the Pennsylvania Section established an award to encourage students enrolled in the agricultural engineering curriculum of Pennsylvania State College to attend meetings of the State Section. The award provides for a paid trip of two members of the Pennsylvania Student Branch of ASAE at one section meeting each year. The students are selected by the Student Branch and one of the two must be a member of the junior class. At the meeting at (Continued on page 730)

New 1952-53 officers of the Pennsylvania Section, ASAE. Left to right: J. B. Kistler, secretary; H. V. Walton, vice-chairman; A. M. Best, chairman

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NEWS SECTION (Continued from page 726)

Wellsboro, the two students who were privileged to be guests of the Section were Robert I. Weaver, a member of the junior class, and Joseph K. Campbell, a member of the senior class.

The next meeting of the Section is scheduled for some time during the spring months and will be held in the Agricultural Building on the Pennsylvania State College campus.

Dewey Long Accepts Assignment in India

JAMES DEWEY LONG, a past-president of ASAE, has been appointed a technologist at the Armour Research Foundation of the Illinois Institute of Technology, Chicago. He will be assigned to one of three of the Point IV projects of the Foundation's International Division in India, which are sponsored by the government. With headquarters in Calcutta, Mr. Long will work with the Damodar Valley Corporation, similar to the Tennessee Valley Authority, in the development of small industry, particularly mechanized, in the area.

Immediately before joining the Foundation, Mr. Long was special assistant to the director of agricultural engineering research in the U.S. Department of Agriculture, a position he had held for four years. His first assignment with USDA sent him to Colombia, South America, where in 1947 and 1948 he assisted the Food Supply Institute of that country in the solution of food storage problems, including the building of modern warehouses and grain elevators and the development of grain fumigation processes.

Mr. Long was associated with the Douglas Fir Plywood Association from 1940 to 1947. Starting as a field engineer, he was advanced to director of research in 1943 and director of education and market research in 1946. While with the Association, he was in touch with the first work on prefab housing in the early 1940's. During World War II, he directed research on military boxing, fireproofing, and wood finishes. His contributions in the general field included plastic impregnation and surfacing of plywood, giant plywood beams for structural uses, and the development of a plywood silo.

Dewey Long was a member of the agricultural engineering staff at the University of California for 18 years, specializing in food, dairy and dried fruit processing. A prolific writer, he is the author of some 40 articles, the majority of which are in the building materials field. A University of California bulletin "The Use of Earth in Adobi Construction," is well known.

Besides his membership in ASAE, Mr. Long is also a member of the American Association for the Advancement of Science, American Society for Engineering Education, Forest Products Research Society, and the Institute of Food Technologists.

Ohio Section Fall Meeting

THE Ohio Section of the American Society of Agricultural Engineers held its fall meeting October 11 in Ives Hall on the Ohio State University campus. The program opened with a talk by C. Howard Bingham, Pennsylvania representative for New Way Farm Sales, Inc., on factors requiring consideration in dairy stable ventilation. This was followed by a talk by John S. Glass, of the Milwaukee office of the U.S. Soil Conservation Service, on water problems dealt with in Soil and Water conservation work.

The meeting was brought to close by a luncheon in the new Ohio Memorial Union, and following the luncheon Karl Butler, farm counselor, Avco Manufacturing Corp., addressed the group on some of the important trends in agriculture.

Alabama Section Fall Meeting

THE Alabama Section of the American Society of Agricultural Engineers held its regular fall meeting at Florence, Ala., on October 3 and 4. Fifty eight members and guests were present.

The principal speaker was Edward A. O'Neal, past-president of the American Farm Bureau Federation, who outlined the growth and development of agriculture in this country with emphasis on the Southeast. Mr. O'Neal's address came after the members had enjoyed a fish fry on beautiful Lake Wilson.

Three tours were made during the meeting. The Section viewed the TVA fertilizer plant which produces superphosphate and the Reynolds aluminum mill which turns out both aluminum stock and finished products. The third tour was made in airplanes over the fertile farm lands of the area showing various soil conservation practices being employed.

The following other subjects were featured on the program: Mechanization in the Tennessee Valley Area, by Fred Stewart, superintendent of the Tennessee Valley substation, the agricultural program of the Alabama State Chamber of Commerce, by E. H. Wilson, director, agricultural division; electrification in the Tennessee Valley Area, by W. R. Walker, electrical development branch, TVA; soil conservation at work, by John M. Lile, and uses of aluminum in farm buildings by C. H. Jefferson, Reynolds Metals Co.

Michigan Section Fall Meeting Program

THE Michigan Section, ASAE, met in the agricultural building on the Michigan State College campus at East Lansing on October 25. The program opened with a talk on mold inhibitors in baled hay by C. H. Eggleton. This was followed by a paper by D. P. Brown on frost control with air movement. The third number on the program featured the subject of analytical and experimental methods for determining optimum size equipment for processing industries, by C. W. Hall, followed by a discussion of the blueberry hoe by D. F. Kampe. Three speakers dealt specifically with the agricultural engineering program at Michigan State College, H. F. McColly, discussing the teaching program, George Amundson the extension program, and W. M. Carleton the graduate and research program. All program speakers were members of the agricultural engineering staff of MSC.

Luncheon was served to the group in the Agricultural Engineering Building.

NFEC Change Planned

A PHASE in the history of National Farm Electrification Conferences closed with the seventh of the series, October 19-21, at Detroit. It closed on the high note of a strong program, with a determination by the Steering Committee that for the immediate future its scale would be held to the proportions of a round table for representatives of the cooperating organizations. Decision to discontinue the convention scale of operations was based on a feeling that this was duplicating functions served by other meetings and not fulfilling the original purpose of providing a forum for interchange of information and viewpoints between leaders of the organizations concerned.

The program developed substantially according to plan. Addresses particularly well received included the welcome to "dynamic" Detroit by Walker L. Cisler, president, Detroit Edison Co.; the keynote talk, "We're Good But We Ought to Be Better," by John Strohm, associate editor, *Country Gentleman;* the banquet addresses, titled "Leadership and What It Takes," by Ralph L. Lee, and "Up-to-Date Ways of Telling a Story on Selling an Idea," by Paul Bagwell, head, department of communication, Michigan State College.

Members of the American Society of Agricultural Engineers contributing to the program and arrangements included H. H. Beaty, Hobart Beresford, Wm. G. Buchinger, J. C. Cahill, E. C. Easter, A. W. Farrall, R. J. Gingles, K. H. Gorham, H. J. Gallagher, G. E. Henderson, T. E. Hienton, A. H. Hemker, W. D. Hemker, R. E. Johnson, E. W. Lehmann, G. W. McCuen, A. D. Mueller, Wm. N. Muir, H. S. Pringle, W. J. Ridout, Jr., C. E. Seitz, E. D. Smith, D. G. Womeldorff.

A Report from the Sanitarians

AT THE 39th annual convention of the International Association of Milk and Food Sanitarians, held at Minneapolis in September, the American Society of Agricultural Engineers was represented by Stanley A. Witzel, professor of agricultural engineering, University of Wisconsin, who is a member of both the ASAE and IAMFS. In addition to representing the Society at this meeting, Mr. Witzel also presented the results of dairy cattle housing research at the University of Wisconsin to the sanitarians.

Among other things, Mr. Witzel reports that those in attendance at the meeting were much in accord with the work which agricultural engineers are doing, especially as it relates to the field of milk and food sanitation, and welcome any and all cooperation which they can give to workers in the sanitation field. (News continued on page 734)

In this picture ASAE Alabama Section Chairman C. A. Rollo is shown presenting Edward A. O'Neal, past-president, American Farm Bureau Federation, with honorary membership in the Alabama Section. Left to right: J. B. Wilson, Mr. O'Neal, chairman Rollo, M. B. Penn, I. F. Reed

Applicants for Membership

The persons listed below have applied for admission to membership or for transfer of membership grade, in the American Society of Agricultural Engineers. Members of the Society who wish to commend or object to any of these applicants, should write the Secretary of the Society at once.

ALDERMAN, ELMER M. — Trainee, Caterpillar Tractor Co., Peoria, Ill.

AVERITT, FORREST I. — Field representative, American Zinc Institute, Chicago, Ill.

BORNZIN, JAMES H.—Assistant chief engineer, International Harvester Co., Memphis Works, Memphis, Tenn.

BRANDENBURG, NORMAN R.—Assistant agricultural engineer (BPISAE), USDA (Mail) Corvallis, Ore.

CARLSON, ERNEST C.—Assistant chief engineer, advanced eng. dept., International Harvester Co., Chicago, Ill.

CARVER, JAMES W., JR.—Irrigation sales engineer, Benton Tractor Co., Corvallis, Ore.

CLAYTON, JOE T.—Instructor in agricultural engineering, Univ. of Illinois, Urbana, Ill.

DILL, JAMES M., JR.—Salesman, Russell, Burdsall & Ward Bolt & Nut Co., Chicago, Ill.

HILL, OLIVER B.—Beekeeper, Harry K. Hill, Willows, Calif.

JACOB, C. M. — Assistant professor of agr. eng., Allahabad Agricultural Institute, Allahabad, U. P., India

MATTHEWS, LAWRENCE J.—Trainee, J. I. Case Co., Racine, Wis.

MESSNER, JACK D.—Trainee, New Idea Div., Avco Mfg. Corp., Coldwater, Ohio

MILLER, EDGAR A., JR.—U.S. Air Force, Lake Charles AFB, Lake Charles, La.

MILLER, HOWARD W., JR.—Farm representative, Pennsylvania Power & Light Co., Allentown, Pa.

MILLER, ROBERT D. — Trainee, John Deere Waterloo Tractor Works, Waterloo, Iowa

MOODIE, ARNOLD—Sales engineer, John Effa Irrigation Co., Chicago, Ill.

MURRAY, DONALD A.—Assistant project engineer, John Bean Western Div., Food Machinery & Chemical Corp., San Jose, Calif.

PAIR, CLAUDE H.—Project supervisor (SCS), USDA (Mail) Boise, Ida.

PARKER, C. T. — General patent attorney, Deere & Co., Moline, Ill.

REESER, ESRAL M. — Design engineer, J. I. Case Co., Burlington, Iowa

RIGEL, ELMER E.—Agricultural engineer, Southeast Colorado Power Assn., LaJunta, Colo.

RITCHIE, EARL A.—Supervisor of field engineering and testing, A. O. Smith Corp., Milwaukee, Wis.

ROSE, DILLARD L.—Irrigation engineer, Atlas Supply Div., Jones & Laughlin Supply Co., Muskogee, Okla.

SCHINAGL, JACK F.—Technical writer, Western Advertising Agency, Racine, Wis.

WELCH, G. BURNS—Assistant agricultural engineer, Mississippi Agricultural Experiment Station, State College, Miss.

TRANSFER OF MEMBERSHIP GRADE

BOND, THEODORE E. — Associate agricultural engineer (BPISAE), USDA, agr. eng. dept., college of agriculture, Davis, Calif. (Associate Member to Member)

KEENEY, L. G. — President, Farmers Mutual Reinsurance Co., Grinnell, Iowa (Affiliate to Member)

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NEWS SECTION *(Continued from page 730)*

Washington Section Features Flood Prevention

AT ITS meeting October 10 in the South Building of the U.S. Department of Agriculture in Washington, the Washington (D.C.) Section of the American Society of Agricultural Engineers heard Richard A. Hertzler, flood control survey office, U.S. Department of Agriculture, discuss the flood prevention program of the Department.

T. B. Chambers, chief, division of engineering, SCS, acted as chairman of the meeting.

A-E Curriculum at Rutgers Accredited

THE agricultural engineering curriculum at Rutgers University is a new addition to the list of such curriculums accredited by the Engineers' Council for Professional Development.

Harry I. Besley, head of the department, reports that the approved curriculum is a four-year program leading to the degree of bachelor of science in agricultural engineering. It is administered jointly by the deans of agriculture and engineering. It has been in effect for the past year.

Minnesota Section Program on Herbicides

THE Minnesota Section of the American Society of Agricultural Engineers presented an interesting program at its dinner meeting in the cafeteria building on the farm campus of the University of Minnesota at St. Paul on October 28.

Following the dinner, John H. Miller, of the U.S. Department of Agriculture, discussed the role of herbicides in agriculture. This talk was followed by a discussion by W. G. Shelley of the O. W. Kromer Co., on the equipment and methods for applying herbicides. Mr. Miller is actively engaged in a weed control research program in cooperation with the University of Minnesota. Mr. Shelley is manager of his company and is concerned with problems in the design, development, and manufacture of equipment for applying weed-controlling chemicals.

Engineering in AAAS Program

A NUMBER of session topics of interest to engineers, arranged by Section M (Engineering) and various other sections of the American Association for the Advancement of Science, have been scheduled for its meeting December 27 to 30 at St. Louis, Mo.

Three concurrent sessions scheduled for the opening morning, Saturday, December 27, will deal with these subjects: "The Nature of Disasters," "Scientific Manpower Research and Engineering," and "Men and Machines." During the afternoon there will be a symposium titled "Disaster Recovery," and a continuation of the program on "Men and Machines."

Biographical directories and rosters of scientists and engineers are subjects to be considered in a Sunday forenoon session of the Conference on Scientific Manpower.

Four of the concurrent sessions Monday forenoon, December 29, will compete for the attention of engineers. They will deal with the topics, "Isotopes in Industry," "National Policy Relating to Scientists, Engineers, and Students," "Methodology in Engineering Research," and "Health Hazards and Health Protection." The latter topic will receive further attention in afternoon and evening sessions the same day. The subject "Carbon 14 Isotope" will be considered in another session during the afternoon.

A third session on the topic "Men and Machines" will be held Tuesday forenoon. "Utilization of Industrial Manpower" is listed as a Tuesday noon luncheon meeting topic. Otherwise the engineering interest in this last day of the meeting will be largely in the medical program dealing with heating and speech aids, communication, and cooperation of medicine and engineering in speech and hearing. It will feature contributions from the Central Institute for Deaf and Washington University.

Irrigation Equipment Manufacturers Meet

THE Association of Sprinkler Irrigation Equipment Manufacturers will hold their fifth annual meeting at the Edgewater Gulf Hotel, Edgewater Park, Miss., November 18-20. Largest attendance in the history of the industry is expected. Featured topics of discussion will include better sprinkler irrigation system field layout and design for more efficient crop production, minimum industry standards of equipment, and the farmer's place in defense planning, in terms of adequate allotments of aluminum.

Nationally known irrigation authorities in the three-day session will discuss new findings in techniques for application of irrigation to specific crops and soils, pumping improvements and studies of irrigation equipment distributor responsibilities. "Cloud seeding" and its relation to irrigation and freight rate studies of interest to the industry will also be discussed.

A special award for "Outstanding Contribution in the Field of Sprinkler Irrigation" will be made on behalf of the organization.

(News continued on page 736)

NEWS SECTION *(Continued from page 734)*

Drainage Conference Scheduled

THE eighth annual drainage conference sponsored by the Mason City (Iowa) Brick and Tile Co., has been scheduled for November 28 and 29, at the Hanford Hotel in Mason City. Object of the conference is to bring to the attention of tile drainage contractors information which will help them improve their service to farmers.

Featured on this year's program are contributions titled "Pumping Stations as Tile Outlets," by Geo. Fonken, Soil Conservation Service, USDA; "Legal Headaches of Tile Drainage," by Fritz Beck, attorney; "Oils, Greases, and Fuels," by a representative of the Standard Oil Co.; a "Travelogue of Greece with Emphasis on Its Drainage Problems," by Paul Jacobsen, Soil Conservation Service, USDA, and "A Means to an End," by Jerry Meldrum, Iowa State College. The last-named will emphasize care of land after a drainage system is completed.

A report by the Iowa Agricultural Extension Service has been scheduled. The Midwest Soil Conservation and Drainage Contractors' Association will hold its fall business meeting during the conference.

The program is open to anyone interested in tile drainage.

Current Point Four Openings

A RECENT release from the U.S. Department of Agriculture indicates a number of current openings for agricultural engineers and other specialists in the Point Four program, based on requests from cooperating countries.

Specific openings are indicated as follows: Brazil, one agricultural engineer; Nicaragua, one extension specialist (agricultural engineer); Saudi Arabia—Iran—Israel, three agricultural engineers (farm machinery); Iran, one agricultural engineer (irrigation); India, one head of agricultural engineering department, nine agricultural engineers, one agricultural engineer (farm power machinery); Indonesia, one agricultural engineer (instructor maintenance).

Among other openings listed, some in fields closely related to agricultural engineering are as follows: Bolivia, one soil scientist; Dominican Republic—Ecuador, two agronomists; Ecuador, one extension advisor (general); Saudi Arabia, one soil scientist; Iraq-Israel, two agronomists; India-Indonesia—Afghanistan, three agronomists; and Indonesia, one machinery operation supervisor and one machinery maintenance foreman.

Most of the openings are in the GS-11 to GS-13 qualification and salary range. Quarters and cost-of-living allowances and post differentials of up to 25 per cent of the base pay apply to some stations.

Applications on Form 57 or requests for further information may be addressed to the division of employment, Office of Personnel, U.S. Department of Agriculture, Washington 25, D.C.

A Correction

AN ERROR in the news report in AGRICULTURAL ENGINEERING for July (page 456), covering the April 25 meeting of the Iowa-Illinois Section, has been noted. The news item indicated that J. R. Carlson, general sales manager, Berry Division, Oliver Iron and Steel Corp., presented a paper on the Berry principle of the generation and utilization of electric power. It should have read that the paper covered the Berry principle of the generation and utilization of *hydraulic* power. The products of the Berry Division of the Oliver Iron and Steel Corp. are entirely in the field of hydraulic power equipment.

NEW BULLETINS

Results of Research in 1951. (64th) Annual Report of the Director, Agricultural Experiment Station, University of Kentucky (Lexington). Among other items this summarizes briefly three agricultural engineering projects on cost of farm house construction, fuels for heating burley tobacco barns, and effects of supplemental irrigation on pasture production.

Design of Nailed Structures, by E. George Stern and Paul W. Stoneburner. Bulletin of the Virginia Polytechnic Institute (Blacksburg) Engineering Experiment Station Series No. 81 (Sept., 1952). Brings together in one volume for convenient reference three related papers by the authors of fundamental considerations in the design of nailed structures, three-member joints for nailed trussed rafters and nailed vs bolted vs connectored trussed rafters.

Heating Practices and Equipment for Curing Burley Tobacco, by Jack N. Krueger. Kentucky (Lexington) Extension Circular 496 (Aug., 1952). Sixteen pages of practical information on ventilation, distribution of heat, fuels, costs, coke stoves, oil burning equipment and gas burning equipment.

How to Get Extra Service from Farm Tires. The Rubber Manufacturers Assn. (444 Madison Ave., New York 22, N. Y.). This is a 16-page illustrated booklet showing recommended practice for removal and mounting of tires, inflation, tractor wheel weighting, inspection, repair, and general care to secure maximum service value from tires used on farm equipment. It includes load and inflation tables for the usual range of farm tire types, sizes, and applications.


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NEWS FROM ADVERTISERS

New Products and Literature Announced by AGRICULTURAL ENGINEERING Advertisers

Three New Self-Propelled Combines

Massey-Harris Co., Racine, Wis., has announced the introduction of three new-model self-propelled combines, which feature large capacity, and will be known as models 90, 80 and 70, replacing the Company's Super 26 and 27 models.

The new Models 90 and 80 have a hydraulic-speed selector and live-axle drive which makes possible complete speed adaptability to specific field and crop conditions, and a safe, fast road speed of 14 mph.

Width of cut on the large Model 90 ranges from 12 to 16 ft, on Model 80 from 10 to 14 ft and on the smaller Model 70 from 8½ to 12 ft.

Balanced separation in the new models is indicated to result from an operating relationship between the size, position, speed and capacity of each unit of the combine, assuring control of grain and straw at every engine speed, through every harvesting step.

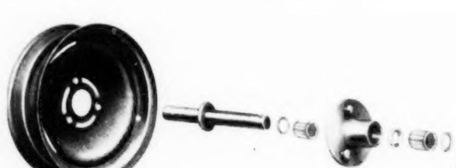
Massey-Harris Model 70 self-propelled combine

Other features include increased comfort and convenience of the operator, with the grain tank, cutter bar and the complete field in view of the operator at all times.

A hydraulic table lift with an adjustable cutter bar enables the operator to cut as high as 33 in, as well as skimming the ground. Three forward-speed controls are in an enclosed drive. The 90 and 80 Models, suitable for all small grains and rice, can be equipped with track-laying treads for muddy rice harvest conditions.

Economy Wheel for Light Applications

French & Hecht Division, Kelsey-Hayes Wheel Co., Davenport, Iowa, has developed a new standarized wheel-hub-spindle assembly for light duty applications on farm equipment. Its purpose is to provide a soundly-engineered light duty package unit suited to a wide range of applications and to serve a quantity market with optimum economy. This economy wheel is intended for loads averaging 750 lb per wheel and for applications such as portable grain elevators, light trailers, lime spreaders, sprayers, etc. Since farmers will attempt to apply any available used auto tire, it is of interest to note that it is physically possible to mount up to and including 8.20 x 15 tires even though such tire capacity is in excess of what the wheel and spindle will carry.



Light-duty French & Hecht economy wheel assembly

Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this bulletin the following listings still current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated.

POSITIONS OPEN—APRIL—O-603-568. MAY—O-619-570, 630-572. JULY—O-712-575. SEPTEMBER—O-741-581. OCTOBER—O-767-583, 767-584, 770-585, 770-586, 759-587, 760-588, 782-589, 783-590, 785-591, 758-592, 778-593, 786-594, 744-595.

POSITIONS WANTED — APRIL — W-582-109. JUNE — W-678-121. JULY—W-694-123, 691-124. AUGUST—W-721-129, 722-130, 693-131. SEPTEMBER—W-735-133, 739-134. OCTOBER—W-762-136, 769-137, 765-138, 775-139.

NEW POSITIONS OPEN

GRADUATE RESEARCH ASSISTANTSHIP for study and development of labor-saving devices to be used in commercial florist crop production in and around greenhouses. Land-grant university in an eastern state. Opportunity for full graduate program leading to MS or PhD deg. BS deg in engineering or equivalent with ability to pursue graduate study in agricultural engineering essential. Some background in commercial flower production or plant sciences desirable but not essential. Usual personal qualifications. Financed for one year with probable extension to three years, including some travel and other expenses. Salary, $1,659 on 12 mo basis. Free tuition. O-824-596

NEW POSITIONS WANTED

DESIGN, development, or research in rural electric or soil and water field in industry or public service, anywhere in U.S.A. BS deg in agricultural engineering, 1951, Iowa State College. MS deg in agricultural engineering expected Jan., 1953, University of Nebraska. Farm background. War enlisted service in Army Signal Corps. Radio repair, one year. Married. Age 30. No disability. Available Feb. 15. Salary open. W-793-141

DESIGN, extension, or teaching in farm structures with college, experiment station or consultant, any location. BS deg in agricultural engineering, 1950, North Carolina State College. Design and advising on farm structures in industry, 6 mo. Enlisted service, civil engineering work, Jan., 1951 to '53, expected date of discharge. Single. Age 24. No disability. Available Feb. 1. Salary open. W-791-142

SALES, or service in power and machinery field with manufacturer in U.S.A., Central or South America, or Scandinavia. Training in mechanical engineering the Technical Institute of Gothenburg, Sweden, completed 1945. Military service 1945-46 (one year) as motor pool mechanic, Coast Artillery, Sweden. Own business in oil burners and well drilling 2 yr. With experimental department of oil burner manufacturer in U.S.A., 6 mo. Sales engineer, mechanical and electrical machinery, in Panama, 2 yr. Presently manager of auto service and repair station. Languages: Swedish, English, Spanish, German. Married. Age 27. No disability. Available on 14 days notice. Salary 500 per month. W-792-143

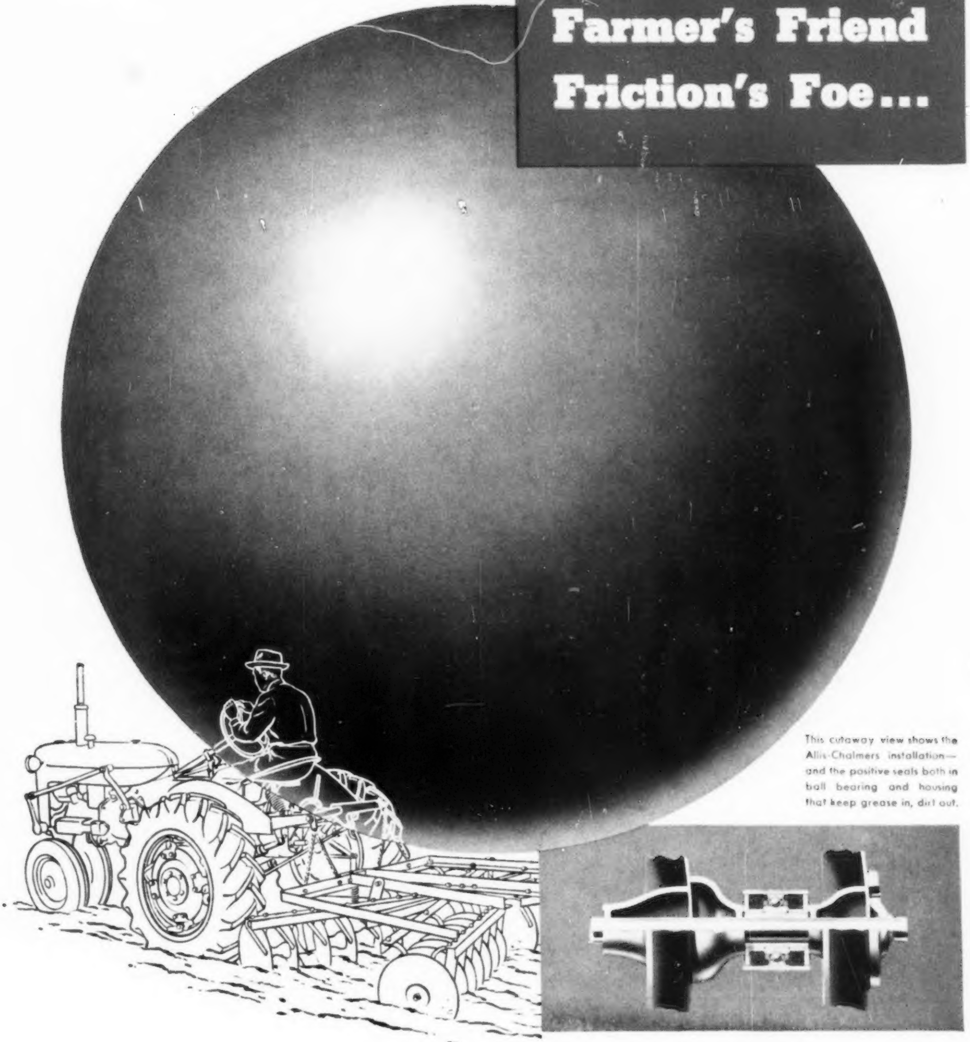
SALES, service, or technical representative in power and machinery, soil and water, irrigation, or product processing, with manufacturer or processor, any location. BS deg in agricultural engineering, 1949, University of Minnesota. Farm background. Timekeeper in manufacturing plant, 7 mo. Hydraulic engineer October 1949 to present. War service in Navy, 3 yr enlisted, one year commissioned. Married. Age 31. No disability. Available on 30 days notice. Salary $4200 min. W-823-144

RESEARCH, writing, field testing, or promotion in power and machinery or rural electric field, with industry in southern state or Europe. BS deg in agricultural mechanics, 1950, West Virginia University. Farm background. Farm representative with electric utility one year. Summer work on university experimental farm. Since graduation agricultural engineer on field testing and research with producer of steel forgings. War noncommissioned service 1½ yr in Army Signal Corps. Married. Age 26. No disability. Available on 30 day notice. Salary $5000. W-810-145

PROFESSIONAL DIRECTORY

RATES: Announcements under the heading "Professional Directory" in AGRICULTURAL ENGINEERING will be inserted at the flat rate of $1.00 per line per issue; 50 cents per line to ASAE members. Minimum charge, four-line basis. Uniform style setup. Copy must be received by first of month of publication.

Farmer's Friend Friction's Foe...



This cutaway view shows the Allis-Chalmers installation—and the positive seals both in ball bearing and housing that keep grease in, dirt out.

NOTHING ROLLS LIKE A BALL

Two new Allis-Chalmers tractor-mounted disc harrows reach new heights in trouble-free maintenance and power-saving rolling ease, through the use of Sealed-for-Life New Departure Ball Bearings in each of the disc gangs.

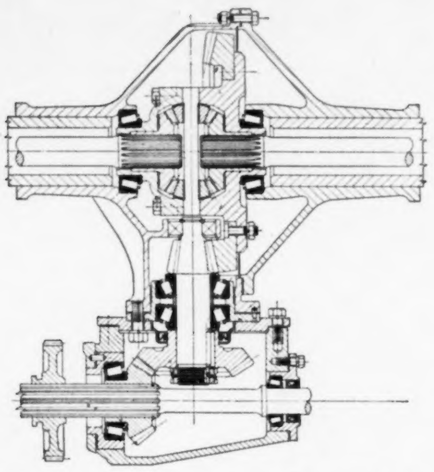
Designed to last for the life of the implement, the N-D-Seal Bearings never require lubricating or adjusting . . . provide a lighter draft which pays off in time and fuel savings.

New Departure Ball Bearings play a big role in farming today . . . simplifying implement design . . . reducing friction and increasing service life wherever shafts turn. Keep your eye on the BALL to be sure of your BEARINGS!

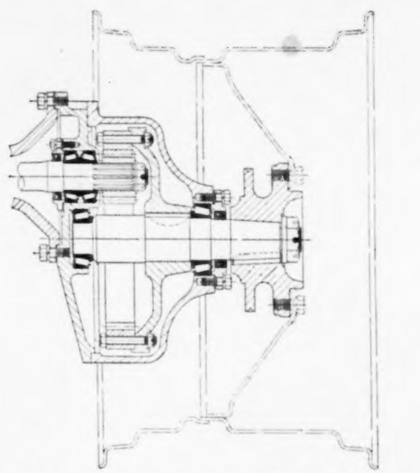
NEW DEPARTURE
BALL BEARINGS

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT

EVERY NEW FARM TRACTOR HAS TIMKEN BEARINGS; MORE AND MORE IMPLEMENTS ARE USING THEM, TOO!



In this John Deere No. 55 Self-Propelled Combine drive, imput shaft and differential bearings are directly mounted and adjusted with thin metal shims. Pinion shaft bearings are mounted indirectly and adjusted by cone spacers.



In the No. 55, Timken bearings on the bull pinion are directly mounted and adjusted by shims. The axle shaft uses two single row Timken bearings directly mounted and shim-adjusted.

How TIMKEN® bearings lick combined loads on John Deere combine

DUE to the use of spiral bevel and helical gears, the transmission and auxiliary drive mechanisms of the John Deere Self-Propelled Combine present tough bearing loading problems. These loads range from heavy radial and moderate thrust loads to heavy thrust loads and moderate radial loads. These exacting conditions were met by the use of Timken® tapered roller bearings. Diagrams above show the bearing applications.

By using Timken bearings, implement engineers solve three of their biggest design problems at once: (1) dirt, (2) combination loads, and (3) rough terrain. Implement users are assured of longer implement life, less chance of breakdown in the field and higher speeds with less frequent lubrication.

Timken bearings hold shafts and housings concentric so that closures are more effective. And with Timken bearings, moving parts rotate freely because smooth surface finish and true rolling motion in the bearing make friction negligible.

For more information about Timken bearings, write now for your free copy of "Tapered Roller Bearing Practice On Current Farm Machinery Applications". The Timken Roller Bearing Company, Canton 6, Ohio. Cable address: "TIMROSCO".

The farmer's assurance of better design →

Tapered Roller TIMKEN BEARING EQUIPPED

NOT JUST A BALL NOT JUST A ROLLER THE TIMKEN TAPERED ROLLER BEARING TAKES RADIAL AND THRUST LOADS OR ANY COMBINATION